Hard Anodizing for Aluminion Pieces -Supporting Friction and Wearing- For The Automotion And Motorcycling Industry

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Abstract

Aluminium pieces are being used more and more in the automotion industry. But they have to support great wearing due to the reaction to some chemical product (oils, gasolines, gasoil, etc). Pieces also suffer an important wearing due to friction and pressing work.

The hard anodizing type II is used and it is observed that with the new aluminium and magnesium alloys (which are not going to be discussed now), together with sealing polymers and silanos a higher resistance against use and wearing is reached.

Therefore, chains formation in the silanes interfase were studied. It was observed the reaction mechanism formed in between the aluminium-metal and the oxide resulting from hard anodizing. The interfase occurring with silane and silane oxide are free radicals of silicon and oxide silicon, respectively, which for the polymer This paper analyzes and try to explain the polymers application in pumps for injecting oil and brake liquide.

Key-words

- Alumnium alloys
- Environment Hard Anodizing, type III
- Silanes and Polimers
- impact minimization

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Anodizing Conditions

All test panels are anodized in 18% sulfuric acid containing 5-7g/L dissolved aluminium. The tank volume es 3000 L and process temperature is 0°± 5 coating thickness is 25 or 60μm.

Taber Wear Resistance

The abrasive wear resistance is measured as Taber resistance according to Taber Tester, model 6061 with two sets AA-5 abrasive wheels, from Taber Industries.

The panels were placed in a dessicator two hour before each weigthting. The wear index is calculated from the weight loss after 10,000 wear cycles. A Type III coating is characterized by a maximum loss of 1.2 to 1.5 mg per 1,000 wear cycles if the copper content is less than 0.5%-2.0% maximum due to copper great contamination. A maximum weight loss of 2.5-4.0mg per 1,000 cycles is allowed for copper rich alloys.

The aluminium alloys of the 1,000 series passes the Taber test **(Table 1)** and the wear performance is independent of coating thickness.

Alloys from the 2000 series passes the Taber test when thickness is 25μm. Increasing the tickness to 60μm reduces the wear resistance and the coating do no pass the test criteria for a Type III coating.

Alloys from the 6000 series pass the Type III wear cruteruam but as thickness increases, the wear index increases. Increasing the thickness from 25 to 60μm results en 72% higher wear index.

Only alloys from the 7000 series do not pass de Taber test. The alloy fails at low and hight coating thickness. However, the wear performance is independent of process time (~thinckness).

For the fous aluminium alloys investigated the 1000 series have the best taber performance. The wear performance for alloys form de 2000 and 6000 series decreases with encreasing thickness.

Compared to the average wear index (n=4), worst case scenario (maximum wear index out of four), the Taber wear index can be as high as +/– 50 %. The deviation from the average value seems to be thickness and alloy dependent.

Alloy	Taber Wear Index (mg/1,000 cycles							
	Thickness = 25μm				Thickness = 60μm			
	Ave (n=4)	St.Dev.	Min.	Max	Ave (n=4)	St.Dev.	Min.	Max
1100	0.40	0.10	0.10	0.60	0.49	0.25	0.40	0.60
2024	0.70	0.12	0.58	0.97	4.98	0.32	4.85	5.50
6061	0.58	0.31	0.19	0.99	1.15	0.15	1.20	1.40
7075	3.00	0.02	3.30	3.66	3.75	0.08	3.80	3.90

Table 1. Taber wear index for four aluminium alloys calculated from weight loss after 10,000 wear cycles

Alloy	Taber Wear Index (mg/1,000 cycles					
	Thickness = 25µm			Thickness = 60µm		
	Front	Rear	Diff.	Front	Rear	Diff
1100	0.42	1.20	0.78	0.35	2.20	1.85
2024	0.90	4.70	3.80	4.70	6.50	1.80
6061	0.98	1.65	0.67	1.10	1.60	0.50
7075	3.30	3.45	0.10	3.70	3.60	0.10

Table 2. Reproducibility of the Taber Testing measured as the Wear Index on the front and the rear side of the test panels for the four alloys investigated

The accuracy of the Taber testing is shown in **Table 2.** Two panels of each alloy series show different wea characteristics from one side of the panels to the other.

Only one test panel out of the five meeting the test criteria of <1.2mg per 1.000 Cycles weight loss shown in Table 1 passed when Taber tested on the rear side. Only the 7000 series showed no change in Wear Index from the front of the rear side.

Acceptance values for abrasive testing according to ISO 10074 is alloy specific. The international standard contains 3 classes and 2 subclasses . Class 1 is alloys except those in class 2. Class 2 consists of two subclasses: Class 2a covers alloys of the 2000 series. Class 2b covers alloys of the 5000 series containing more thar 1-2% magnesium and alloys of the 7000 series. Class 3b is all other casting.

According to ISO 10074, class 1 alloys are allowed to loose 1.2 to 1.5mg coating per 1.000 cycles. Acceptance criterio for class 2a and 2b are 4.0 and 3.5mg per 1,000 cycles. Alloy 1100 and 6061 passes the acceptance values- Alloy 2035 does pass if the coating thickness is low. Independenta of thickness alloy 7075 (class 2b) is the only alloy that does not meet the minimum requirement of ISO 10074.

ISO 8251 Wear Testing

The test method is a reciprocating test specially designed for abrasive wear measurements on anodized aluminium. The surface of the test piece reciprocates on a wheel, which is covered by an abrasive strip. The abrasive wheel turns 1/500 full rotation for each reciprocal movement or double stroke (DS) of the sample. It is pressed against the test surface by a spring load of 5.1N. After 500 DS the abrasive tape is changed and the wear test can be continued. The wear is presented as number of DS needes to remove 1.5µm-1.0µm to 1-2mg of alumnium oxide.

The thickness before and after the abrasive test is measured with an Eddy Current meter calibrated between 10 and 55µm. Each thickness measurement is the average of 5 to 25 thickness readings.

The wear data obtained by test method can be divided into initial and post wear. The former is related to the first 500 DS and is influenced by the surface conditions of the aluminium oxide coating, surface roughness and the degree of powdering.

Precision of coating	Thicknerss (μm ± 1 St. Dev. n=25)		
	# 1	# 2	# 3
# 1	38.0 ± 0.9	37.2 ± 0.8	37.6 ± 0.8
# 2	35.5 ± 0.5	35.7 ± 0.5	35.5 ± 0.7
# 3	35.8 ± 0.6	36.0± 0.7	36.2 ± 0.4
	Average = 36.38 ± 0.65		

Table 3. Precision of coating thickness measured with an Isoscope

The wear after 1.500 DS represents the post wear and in influenced by the compactness and composition of the anodic coating . It is not influenced by the surface conditions.

The precision of coating thickness, measured with an Isoscope is shown in **Table 3.** Three precision coatings measured the coating thickness three times and each thickness is the average value of 25 readings. The average coating thickness is 36.38μ with a standard deviation of 0.65.

The results of the wear test are shown in **Table 4**. For all four alloys investigated, the initial wear resistance after the first 500 DS is approximately 30 to 40% less compared to resistance after 1.500 DS.

Alloy	ISO 8251 Wear Index (cycles/μm)							
	Thickness = 25μm				Thickness = 60μm			
	500 D.S.		1500 D.S.		500 D.S.		1500 D.S.	
	Ave.	St.Dev	Ave	St.Dev	Ave	St.Dev	Av	St.Dev
1100	140	25	200	25	140	17	195	25
2024	80	15	120	18	45	4	75	5
6061	145	12	180	20	121	18	180	15
7075	120	12	170	15	89	20	140	12

Table 4. ISO 8251 Wear Index for the investigated alloys calculated, as numbre of cycles (D.S.) needed to remove 1μm hardcoat. For each reading n=4

For alloy 1100 the initial wear shows the surface conditions are independent ocoating thickness. The three otrher alloys shows reduced wear resistance with increasing thickness. The degree of reduced wear resistance is alloy specific: -20% (6061) and -30% (7075).

The post war resistance of alloy 1100 and 60612 is of same magnitude and is not influenced by couting thickness. The poste wear resistance oa alloy 2024 and 7075 is less compared to the former alloys and the wear resistance decreases with increasing thcikness.

The reduced post wear of alloy 7075 could be a result of increased initicial wear. A compensated wear resistance calculated bu subtracting the wear after 500 DS from wear after 1.500 DS shows the reduced wear resistance for alloy 7075 is caused by increased initial wear. The compensated wear index is 220 cycles/μm ±55 (25μm) compared to 190 cycles/μm ± 40 (60μm).

The decrease post wear resistance for alloy 2024 when thickness is increased is not only related to changes surface conditions 170 cycles/μm ± 30 (30μm) compared to 90 cycles//μm ± 5 (60μm). The compactness and the composition on the oxide film changes with process time.

In worst case scenario, the resproductibility of the lowest wear resistance within each alloy group is 15 below the average resistanca; ranging from 4% to 15% with an average of 11%.

The accuracy of the test method is shown in **Table 5.** The wear resistance's after 1500 DS measured as the difference from the front to the rear side is in worst case ±15%. The reproductibilite for the initial wear is in worst case ±15% (data not shown).

Alloy	**ISO 8251 Wear Index (cycles/μm, 1500 D.S.)**					
	Thinckness = 25μm			Thickness = 60μm		
	Front	Rear	%	Front	Rear	%
1100	210	209	1	180	179	-1
2024	115	125	11	65	69	4
6061	200	190	-11	178	168	-6
7075	170	170	7	140	135	-5

Table 5. Reproductibility of the ISO 8251 Testing measured as the Wear Index on the front and the rear side of the test panels for the four alloys investigated.

ISO 10074 Wear Testing

The load size of the abrasive wheel is 20.0N compared to 5.0N in ISO 8251. Furthermore, the abrasive tape is silicon carbide paper of 240 mesh size. In ISO 8251, the mesh size is 320. The Relativa Mean Specific Abrasion Resistance (RMSAR) acceptance values are shown in Table 7.

The wear resistance according to ISO 10074 compensates for initial wear is identical to 200 DS of the abrasive wheel. Depending on alloy, post wear is either the resistance after 500 or 800 DS. The abrasive resistance can be measured as weight loss or thickness reduction.

The wear performance measured as numbre of DS per micron thickness reduction for alloy 110 is shown in Table 6 (thickness = 60μm). The wear performance is also compared to the compensated wear after 500 DS. Each wear index is approximately 19% lower compared to wear after400 DS and 800DS. A lower initial wear is in agreement with the results of wear testing according to ISO 8251.

The initial wear is also approximately 25% lower compared to the performance after 500 wear cycles, when the index is calculated as cycles per 1-1.5mg weight loss (Table 6).

Alloy	200DS	500DS	800DS	(500-200)DS	(800-200)DS
1100	60 ± 5	70 ± 5	65 ± 5	75 ± 5	70 ± 5
1100	60 ± 5	70 ± 5	65 ± 5	75 ± 5	70 ± 5
1100#	65 ± 5	75 ± 5	65 ± 5	85 ± 10	70 ± 5
6061	35 ± 4	60 ± 5	65 ± 5	87 ± 11	70 ± 5

Table 6. Abrasive wheel performance cycles per micron and cycles per mg weight los (#) of alloy 1100 and cycles per micron of alloy 6061 according to ISO 10074

Based on the results from Table 6 compensated wear for alloys of Class 1 can be calculated using the wear performance after 500 DS.

The wear performance for alloy 6061 is also shown in **Table 6**. Compared to alloy 1100, the higher compansated wear is caused by a significantly lower initial wear.

The reproducibility of the test method is investigated as the wear performance on the front and the rear side of each test panel. The overall accuracy is ±5 cycles per micron, calculated as the standard deviation of all 6 measurements.

The wear performance using a sample siza of 5 thickness readings is not different from a sample size of 25 measurements.

Assuming the wear performance of alloy 1100 is identical to the reference alloy 1050, calculation of wear index shall be made using 70 cycles per micron as reference wear.

	RMSAR % of Standard Specimen
1	≥ 90% (800 D.S. to 200 D.S.
2a	≥ 40% (500 D.S. to 200 D.S.
2b	≥ 60% (800 D.S. to 200 D.S.
3a	≥ 60 % (500 D.S. to 200 D.S.
3b	≥ 30% (500 D.S. to 200 D.S.

Table 7. Acceptance values for abrasive wheel test according to ISO 10074

Panel	Cycles / μm		Diff. %
	Front	Rear	
#1	80	70	10
#2	70	65	5
#3	70	65	9
Average = 70 cycles ± 8			

Table 8. Reproducibiliti of ISO 10074 wear testing for alloy 1100

Microhardness

The microhardness measured as the average of 7 indents for the investigated alloys (n=4) is shown in **Table 9**. Only alloy 2024 shows a decreasing microhardness with increasing thickness.

Alloy	Microhardness ($HV_{0.010}$) (n=4)	
	25μm	60μm
1100	370 ± 15	370 ± 15
2024	320 ± 15	280 ± 18
6061	360 ± 17	360 ± 15
7075	320 ± 15	310 ± 14

Table 9. Microhardness versus thickness

According to ISO 10074, only alloy 2024 (>250 $HV_{0.05}$) passes the criterio form microhardness. Minimum hardness for class 1 alloys is 400 $HV_{0.05}$. However, the microhardness shown in **Table 9** is measured using a load size of 8-12g.

Discussion

It is generally accepted microhardness is a measure of wear performance of coatings. National and International Standards specify acceptance criteria for both wear resistance and microhardness.

The wear indexes presented in this paper shows a correlation between microhardness and wear resistance is alloy specific and dependent on the test method. Both Taber and ISO 8251 testing on alloy 2024 shows reduced wear performance with increasing thickness. The reduced performance is correlated with reduced microhardness. However , Taber testing of 6061 alloy shows reduced wear performance with increasing thickness, even tough the microhardness is independent on thickness. With increasing thickness, ISO 8251 testing identified a reduced initial wear and a constant post wear. If the post Wear, which is influenced by the compactness and composition of the oxide coating, is independent of thichness, so should the microhardness.

The result presented in this paper show thar reproducibility of wear performance according to ISO 8251 is better than Taber testing (5% compared to 60%). Furthermore, it can not be recommended to do Taber testing on both sides of a test panel.

Compared to Taber testing, wear performance according to ISO 8251 can be made on actual parts, not only coupons. The test method is faster and is not influenced to tha same degree by wear residues.

The test procedures in ISO 8251 and ISO 10074 are in disagreement. Furthermore, alloy 1050, which is the reference specimen in ISO 10074, is not available in many coutries.

The wear performance in both ISO standards ccan be made using thicknee reduction or weight loss. The number of double strokes in abrasive wheel testing according to ISO 10074 can be reduced from 800 DDS to 500 DS. The sample size of Fischerscope thickness measurements is less important. The wear index calculated, as the average of 5 thickness readings is identical to indexes obtaines by a sample size of 25.

Key-words

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- Silanes and Polimers
- Impact minimization

From this work, silanes and polymers minimizacion impact are unfinished

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