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K. JAKÓBCZAK[1*], R. KOWALIK[1]

CORROSION PROTECTION OF SELECTED ALUMINUM WROUGHT ALLOYS APPLIED IN THE AUTOMOTIVE INDUSTRY

The paper aims to review the corrosion properties of selected aluminum alloys applied in the automotive industry which are used in heat exchangers, bodyworks and car wires. Particular attention was focused on application of selected chemical compounds which added to corrosive environment in certain amounts lead to decrease of corrosion rate of protected aluminium alloy. Considered different environmental conditions which are simulating real vehicle exploitation. At review analyzed ability to application mentioned compounds on automotive parts, because there is needed fill of following requirements: environmentally friendly, relatively inexpensive and characterized by long-term performance under certain conditions. Main conclusion of review is that there are needed extension of research regarding to application of inhibitive compounds especially on the surface of cars wires.

Keywords: corrosion; car wires; corrosion inhibitors; heat exchangers; aluminum alloys

1. Introduction

During the last decade, social consciousness regarding climate changes has been grown significantly. The leading root cause of these changes is the excessive emission of CO_2 into the atmosphere. One of the primary sources of carbon dioxide emission is air pollutants from automobiles, especially those running on fuel (gasoline, diesel, LPG). Engineers are working on technologies that limit and reduce fuel consumption by releasing cars powered by electricity or hydrogen. In parallel with the development of zero-emission cars, engineers are working to reduce the weight of the vehicles. Lighter cars have many advantages, such as lower energy consumption, better road performance and less wear on roads and bridges. Nowadays, the main bottleneck in developing alternative energy cars is charging as the process is time-consuming and the network of charging stations still does not cover the road network at the petrol station level. As the total weight of the vehicle decreases, the range per charge will increase. One of the solutions to reduce the weight of cars without eliminating safety and comfort systems is to replace construction materials such as steel with others that meet the requirements and are lighter at the same time. Because aluminum is three times lighter than steel, the wide use of this material in the automotive industry has significantly reduced the demand for fuel, translating into financial savings for shipping companies and reducing the negative impact of transport on the environment.

Aluminum is widely used as a construction material in the automotive industry due to its excellent mechanical properties obtained by alloying with some elements and relatively good electrical and thermal conductivity. There are wide possibilities to obtain an alloy with required properties for specific applications depending on additives and processing conditions. There are two main metallic materials that can be replaced with aluminum alloys. The first is copper, which is currently used in high-power transmission systems and heat exchangers. Iron is the second metallic material that can replaced by aluminium in interior panels, car frames and exterior car bodies. One aspect limiting the broader use of aluminum in the automotive industry is insufficient corrosion resistance. Under normal conditions, the metallic surface of aluminum is covered with a passive protective layer, but the presence of chloride ions, such as road salt, constantly breaks this protection and initiates corrosion. Depending on the metallic structure of the aluminum alloys, the process of galvanic corrosion may be significant. On the other hand, the processing conditions also influence the corrosion phenomenon.

[1] UST AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN KRAKÓW, FACULTY OF NON-FERROUS METALS, DEPARTMENT OF PHYSICAL CHEMISTRY AND METALLURGY OF NON-FERROUS METALS, AL. MICKIEWICZA 30, 30-059 KRAKÓW, POLAND

* Corresponding author: jakobcza@agh.edu.pl

2. The aim of the article

The paper aims to review the corrosion properties of selected aluminum alloys used in the automotive industry. Particular attention was paid to chemicals that can be used as corrosion inhibitors of aluminum and its alloys in alkaline and chloride environments, simulating operating conditions of selected car components. It is important to use in the automotive industry materials which are environmentally friendly, relatively inexpensive and characterized by long-term performance under certain conditions.

3. Review

The paper contains an overview of the alloys Al3003 and Al4343 used for heat exchangers and the body alloys that forged aluminum alloys from the 5xxx, 6xxx and 7xxx series. The alloys used in the production of automotive cables contain over 99.5% aluminum (1370 and 1350) or Al-Mg-Si alloys which are also applied for car wires especially for thinner crossections.

3.1. Aluminum alloys applied for heat exchangers

Metallic materials used in the automotive industry for heat exchangers and air-conditioning systems should have the following properties: thermal resistance to elevated temperatures and sudden temperature changes, good mechanical properties related to relatively low weight (good ratio of mechanical strength to density), low susceptibility to corrosion. Due to the economic aspect, the aluminum alloys of the 3xxx series meet these expectations. Corrosion resistance is the main parameter that is not easy to control and is sensitive to external factors. Although alloys of aluminum with manganese are relatively less susceptible to corrosion, the corrosion resistance may decrease with an increasing proportion of alloying elements. Chemical compositions of alloys applied at cars heat exchangers are listed in TABLE 1 [1].

TABLE 1

Chemical composition of alloys applied at cars heat exchangers (percentage values)

Alloy	Fe	Si	Cu	Mg	Mn	Zn	Al
AA3003	0.7	0.6	0.05	0.05	1.0-1.5	0.1	balanced to 100
AA4343	0.8	6.8-8.2	0.05	0.05	0.1	0.2	balanced to 100

Yoshiyuki Oya et al. investigated the effect of the presence of silicon (Si) on intergranular corrosion. The presence of silicon in the alloy leads to an enhancement of its mechanical properties. At the same time, an increase in the corrosion rate was observed with increasing silicon content and after heat treatment. Ethylene glycol is a compound used as a coolant in heat exchangers. It is characterized by good resistance in a wide temperature range and low production cost [2].

Chen Xin et al. have analyzed the relationship between temperature and corrosion rate for the ethylene glycol-water solution in the presence of chloride ions (NaCl 0.1M / liter). Their results showed that for the anode reaction, the corrosion rate increases with increasing temperature. Cathodic reaction ($O_2 + 2H_2O + 4 \rightarrow 4OH$) if amount of oxygen is limited there is observed forming of aluminum alcohol compound) achieved the highest rate at the temperature equal 60°C. With increasing temperature, accelerated pitting corrosion was observed by forming micro galvanic cells between the aluminum matrix and the second phase particles [3].

AA4343 is used as a brazing material in automotive heat exchangers. The structure of the AA4343 alloy consists of large Al grains surrounded by multi-phase Al, Si, and αAl (Mn, Fe) Si deposits [4].

S. Tierce et al. investigated the corrosion properties of AA4343 in an inert environment (water-ethylene glycol) with and without chloride ions. During the brazing process, both alloys are heated to a temperature between the melting point of the alloys. The connections between the tape cores made of AA3003 and AA4343 solder were tested. The corrosion analysis was performed under various thermal conditions. It has been observed that the central area of corrosion of AA4343 alloy are α (Al (Mn, Fe) Si) phases, which also lead to defects in the protective passive layer. With the increase in temperature (the operating temperature of automotive heat exchangers is in the range of –30°C to over 100°C), an increase in the solubility of the alloy was noticed (for AA4343 alloy). The presence of ethylene glycol (the main coolant compound) in an amount greater than 55% leads to the self-improvement of the passive layer on the AA4343 alloy [4,5].

Studies by A.R. Yazdzad et al. on the anticorrosive properties of propargyl alcohol and tartrate ions showed that in 0.5% NaCl solution, the corrosion rate of alloy 3003 decreased in the presence of propargyl alcohol at a concentration of 1.5×10^{-3} M. Analysis of electrochemical measurements such as polarization curves and Nyquist plots was demonstrated decreasing intensity of anodic dissolution processes. The limitation of the cathode process is potentially due to the formation of a monolayer on the surface of the test alloy. The monolayer formed in this way is responsible for the decrease of oxygen diffusion. The analysis of the influence of tartrate ions on the corrosion process showed a temporary limitation of oxygen reduction due to slowing diffusion. Anode reaction – aluminum dissolution was limited by the adsorption process. The study of the synergistic nature of the inhibitory properties for propargyl alcohol and tartrate ions showed that the corrosion rate was the lowest when the concentration was 5:2 (potassium sodium tartrate to propargyl alcohol) [6].

Y.Liu and Y.F. Cheng investigated the influence of ethylene glycol in a corrosive environment on the corrosion rate of aluminum alloy 3003. In their research studied inhibitors based on sodium gluconate, sodium cinnamate, sodium molybdate, sodium chromate, and sodium nitrate. Compounds were added at a concentration of 1 wt.%. The substances slowing the corrosion rate due to the passivation of the alloy surface and a decrease in the anode current density. The best results were obtained for sodium cinnamate and sodium citrate [7].

On the other hand, the corrosion inhibition mechanism may be based on forming a protective layer on the surface of the alloy. Y.Liu and Y.F.Cheng investigated the effect of cerium ions on aluminum alloy 3003 in aqueous ethylene glycol. The corrosive environment consists of 50% ethylene glycol and 50% deionized water. The concentration of cerium ions as $CeCl_3$ was 0.003 M. The result of this experiment showed the protective nature of cerium ions due to the formation of Ce (III) oxide and/or Ce (III) hydroxide on the alloy surface. During the exposure of the tested alloy to the prepared environment, a surface layer is formed, which leads to the avoidance of a galvanic reaction between two phases [8].

Brahim El Ibrahimi et al. investigated the inhibitory properties of cysteine against corrosion of aluminum alloy 3003 in a 2% NaCl solution. Their results showed that the inhibitory effect depends on both the pH value and the inhibitor concentration. In an alkaline environment, cysteine has good inhibitory properties. On the other hand, in an environment with a pH of 2-8, cysteine is a factor accelerating corrosion even at a lower concentration [9]. Chemical compounds obtained from natural sources, including plant extracts, oils, or drugs, are classified as green corrosion inhibitors.

Al 3003 corrosion in an acidic environment was investigated by M. Chadili et al. It was shown that in 1M HCl solution, aluminum alloys are not resistant to corrosion due to passive dissolution of the film and reaction of aluminum with HCl. The addition of the liquid olive oil (pH = 5.22) reduces the corrosion rate of Al3003 in an acidic environment. During the experiment, the liquid concentration from the oil mill was up to 6 mg/liter. The adsorption characteristics are combined: in this case, both chemical and physical adsorption occurs [10]. Another green corrosion inhibitor that has been tested with Al3003 is phorbia hirta extract. In an article published by L. A. Nnanna et al. [11] the inhibitory compound was tested in the acid [0.5M HCl] and alkaline [0.25M NaOH] environment. The inhibitor was analyzed over a concentration range of 0.1 to 0.3 grams per liter. The obtained results showed inhibition of corrosion in the hydrochloride solution by limitations of the cathodic and anodic reaction, which were reduced due to the presence of bonds in the extracts. In acidic environments, corrosion was limited due to pure physical adsorption, while in alkaline corrosion rate was limited due to combination of physical and chemical adsorption. It has been shown that the effectiveness of the inhibitor decreases with increasing temperature. The presence of chloride ions leads to pitting corrosion [11].

3.2. Aluminum alloys applied for car body

One of the main areas where vehicle weight can be reduced is the bodywork. There are three series (5xxx, 6xxx and 7xxx) that can replace steel among the aluminum molding alloys. Extruded aluminum is used for car frames: car pillars, stringers and bumpers are made of 5xxx series aluminum. The advantages of the alloys in question are following: relatively low manufacturing costs, good cold forming properties and good corrosion resistance. For visible metal surfaces such as doors, car roof, exterior panels, 5xxx alloys cannot be used due to the possibility of making Lüders tapes. For this type of application, alloys from the 6xxx series are used, which also have better mechanical properties. Despite their higher production costs, due to their heat treatment, they are a reasonable choice. In areas where the highest mechanical properties are desired (undercarriage reinforcements, bumpers), Al alloys of the 7xxx series (mainly used in the aerospace industry) are used, which have the best mechanical properties among aluminum alloys.

3.2.1. Aluminum series 5xxx

Among aluminum alloys from 5xxx series there are two most significant types: AA5052 and AA 5083, chemical composition of alloys are listed in TABLE 2 [12,13].

The corrosion properties of the cold-deformed AA5052 alloy in the seawater environment (pH = 8.67) were investigated by O.I. Sekunowo et al. The results of tests of samples with different deformation values (by rolling) showed that the increase in the corrosion properties depends on the reduction of the sample size. Along with the increase in the degree of deformation, an increase in the concentration of Mg2Si fractions, which form microgalvanic cells and lead to pitting corrosion, was observed. Based on the conclusions from the tests described above, it can be concluded that the deformation of the material used should be carefully selected for applications where high corrosion resistance is required [12]. Similar conclusions are presented in an article published by Peng Zhou et al. where a cold-deformed 5052 alloy was also tested. The material was processed by HTP (High Pressure Torsion). One of the main conclusions of the research was following: along with the reduction of grain size caused by larger deformation, the corrosion rate increases. The observed pitting corrosion was more intense in areas where Fe-Si rich intermetallic compounds were present [14].

The corrosion inhibitors for AA5052 were studied by Chong Zhu et al. [15] They examined the influence of glutamic acid and cerium ions in NaCl 3 wt.% solution on the

TABLE 2

Chemical composition of alloys 5xxx series applied at bodywork (percentage values)

Alloy	Mg	Mn	Si	Fe	Ti	Cu	Cr	Zn	Ni	Zr	Al
AA5052	2,399	0,1	0,25	0,391	0,05	0,001	0,3	0,1	0,2	0,5	balanced to 100
AA5083	4,9	0,5	0,13	0,3	0,03	0,08	0,13	—	—	—	balanced to 100

corrosion process. In that case mechanism of corrosion protection was based on forming a layer on the aluminum surface. The most significant decrease of corrosion rate was observed after combining cerium nitrate and glutamic acid compounds, which form a membrane with adsorption properties. The highest efficiency of inhibitor was registered when there were combined compounds in the following composition: for 0.05 mM Glutamic acid ($C_5H_9NO_4$) + 0.30 mM Ce^{3+}. Application of mentioned compound caused limitation corrosion rate up to 85,4% [15].

S. Gudić et al. examined the corrosion inhibitive properties of various types of honey for AA5052 alloy in a 0.5M NaCl environment. The mechanism of corrosion protection was based on forming a layer on the surface of the tested alloy. The physical adsorption of organic compounds placed in honey on the metallic surface takes place. The highest inhibiting efficiency for oak and carob tree honey was observed [16].

J.C. Chang et al. investigated the corrosion properties of 5083 aluminum alloy depending on the microstructure. The main point of publication was focused on stress corrosion cracking. Alloy sensitization at elevated temperatures performed to increase mechanical properties leads to forming precipitation of beta phase (Mg_2Al_3) at grain boundaries. The achieved phases have a highly anodic character and lead to galvanic corrosion. The influence of homogenization on 5083-H321 alloy was examined by Yuanchun Huang et al. The final results showed negative influence of homogenization for corrosion resistance [17].

Corrosion inhibitive properties of lanthanide salts were studied by M.A. Arenas et al. The mechanism of corrosion limitation is based on forming precipitation of cerium compounds Al6-(Mn,Fe,Cr) [13].

5083 aluminum alloy has weak corrosion resistance in an acidic environment. The research focused on corrosion inhibitors for 5083 alloy was released by H. Hachelef et al. The inhibitive properties of the solution containing propolis extract were examined in 1M HCl solution. The mechanism of corrosion rate limitation is based on the adsorption of the inhibitor on the metallic surface [18].

3.2.2. Aluminum series 6xxx

6xxx series aluminum alloys are classified as more corrosion resistant than Al alloys with the main alloy additions: Cu or Zn. W.J. Liang et al. studied the corrosion properties of 6xxx alloys. The corrosion mentioned above properties depends on one of the main advantages of the 6xxx series, namely the ability to age hardening with Mg_2Si precipitations. The composition of the precipitations increases the possibility of local corrosion (pitting and intergrain corrosion). As the proportion of Cu in the alloy increases, the resistance to intercrystalline corrosion decreases. The presence of Si in the alloy composition also increases the probability of intergranular corrosion, but when an insulating passive layer (SiO_2) is formed, the corrosion rate is significantly reduced. Artificial aging increases the susceptibility to corrosion [19]. Aluminium alloy A6061 is enriched by following elements: 1% Mg, 0.6% Si, 0.23% Cu, 0.16% Fe, 0.12 Cr and 0.05% Mn [20].

A6061 B. Zaid et al. investigated the corrosive properties of AA6061 alloy depending on the pH of the environment and exposure to chloride ions. The test results showed that even a small concentration of NaCl solution (0.003 wt.%) leads to pitting corrosion. The increase in the concentration of NaCl ions (up to 5.5 wt.%) caused a slight increase in the corrosion rate. A metal surface exposed to contact with an acidic or slightly neutral environment is dissolved due to pitting and general corrosion processes. Only general corrosion was observed with alkaline solutions. A noticeable decrease in the corrosion rate in a neutral solution (pH = 6) was observed [20].

Corrosion inhibitive properties of sodium benzoate for AA6061 alloy were studied by R. Rosliza et.al. Analysis was performed in a tropical seawater environment. The mechanism of corrosion inhibition in the mentioned case was based on a cathodic reaction. The addition of inhibitive compounds did not lead to a change of corrosion mechanism. The decrease of corrosion rate was caused due to forming a passive film on the metallic surface [21].

Da Quan Zhang et al. studied the influence of addition ammonium heltamolybdate and calcium gluconate on corrosion process AA6061 in 3%NaCl solution. A significant reduction of corrosion was observed after adding a combination of ammonium heltamolybdate and calcium gluconate at a ratio of 4:1 (AH:CG). The presence of ammonium heltamolybdate provides inhibition of corrosion due to adsorption. On the other hand, the role of calcium gluconate was to improve protecting parameters by increasing the thickness of protecting layer [22].

Ethyl-2-Amino-4-Methyl-1,3-Thiazole-5-Carboxylate was studied as a corrosion inhibitor of AA6061 alloy in a 0.05M HCl environment by K. Raviprabha et al. Experiments confirmed that the corrosion inhibition of metallic surface takes place by chemical adsorption mechanism. It was observed the forming of protective film [23].

Daquan Zhang et al. investigated corrosion protection by hydrolyzed fluorinated alkyl silane. This is a layer based on the compound, which includes well-dispersed fluorinated-decyl polyhedral oligomeric silsesquioxane. The mechanism of corrosion rate limitation is caused by shifting corrosion potential to the range of positive value. The advantage of applying this compound is the transparency of the layer and the ability to self-renew [24].

3.2.3. Aluminum series 7xxx

Aluminum alloys from 7xxx series find application in automotive. The main advantage of 7xxx series, among other aluminum wrought alloys applied in automotive, are high mechanical properties. Yield strength is twice higher than for 6xxx alloys and this property cause 7xxx alloys also to find application in the aircraft industry [25].

As for other aluminum wrought alloys, series is also susceptible to corrosion due to formed galvanic cells on the metallic surface. This phenomenon also leads to a discontinuity in the passive layer [26]. AA7075 aluminium alloy is enriched by following elements: 5.6% Zn, 2.5% Mg, 1.5% Cu, 0.5% Fe, 0.4% Si, 0.2% Ti, 0.3% Mn, 0.25% Cr, content of other additions is equal 0.15% [27].

Corrosion inhibitive character of berberine for 7075 aluminum alloy in 3.5% sodium chloride solution was studied by Ambrish Singh et al. Result of research confirmed the ability to decrease the corrosion process of alloy by formation of adsorbing layer [28].

Pitting corrosion of 7075 was observed even at 0.05M NaCl solution. G. Bereket et al. investigated the influence for coorosion rate of $NaNO_3$ compound with added amino acids or hydroxycarboxylic acids. Experiments were performed in solutions with different pH values (4,5,7,8). The results showed that the addition of amino acids leads to decrease corrosion intensity in an acidic environment. Also, the inhibitive properties of hydroxycarboxylic acid in neutral and alkaline solutions were observed. These results confirmed that the organic compound could replace toxic chromates, which are frequently applied to protect aluminum alloys [29].

The identical corrosion protection mechanism was observed by Wanying Liu et al. during their studies on the inhibitive properties of 8-hydroxyquinoline [28].

Przemyslaw Kwolek studied corrosion of the 7075 alloy in an acidic environment (H_3PO_4). In those experiments, the influence of the addition of sodium molybdate to the corrosive environment was also investigated. The result of that experiment indicated the inhibitive properties of that chemical compound. During reaction with orthophosphoric acid, there is formed heteropolyoxomolybdate species, which has adsorbing properties. That is the reason for the decrease of corrosion significantly [30].

3.2. Aluminum alloys applied for car wires

Over the years technical development of the automotive industry was growing significantly. Nowadays, cars from the budget segment include many safety systems, infotainment (e.g., radio, GPS), and equipment that improves travel comfort like air condition systems. Every feature need cables for power delivery and signal transition. In the case of electric/hybrid there are also necessary to power transition wires requires good effectiveness, in fully electric vehicles, voltage values are equal even to 1000 V (CCS2 charging system). The base material which was applied for car wires manufacturing is copper due to excellent electrical conductivity. However, issues with stable receive cost and significant weight will significantly impact car weight with technical advances. That situation determined research on alternative alloys which will replace copper. Aluminum is currently the best available solution: low density equal 2.7 g/mm^3 (vs Cu 8.96 g/mm^3) and a more stable price than coppers. Aluminum is also a metal that is easy to recycle. Unfortunately, aluminum has lower electrical conductivity (twice worse than Cu), but cable with the same electrical parameters is twice lighter than copper. Another advantage of aluminum is good compatibility with insulations. There is no occurring reaction with rubber, and due to that, aluminum cables are easier to recycle after the product end of life.

Another issue that requires improvement are corrosion properties, especially with a connection between alumina cables and copper contacts. This combination leads to galvanic corrosion.

For car wires, two essential groups of aluminum alloys find the application here. Aluminum alloys with high Al content over 99.5%: Al AW-1350 (99.5%) and AW-1370 (99.7%) rest part of alloy composition is completed by Fe and Si. Due to excellent electrical performance, these alloys find application at high voltage powertrains where cross-sections of cables are bigger than 6 mm^2. The second group of alloys applied in car harnesses is Al-Mg-Si alloys, mainly 6101 and 6201 alloys with better mechanical properties than high content aluminum alloys. Cause those alloys from the 6xxx series find application lower cross-section cables till 0.5 mm^2. At TABLE 3 presented certain chemical composition of alloys.

The drawing process obtains aluminum wires, and the count of steps depends on demanded final cross-section. Depending on the process might occur need of alloy aging to release inner stress gained during metalworking. During the cables drawing process there occur changes of alloys microstructure, leading to mechanical and corrosion properties changes. Reinforcement of aluminum alloys applied for car wires production there can be achieved by hydrostatic extrusion [31,32].

Rossana Gravina et al. studied the influence of the cold drawing process for corrosion of AA1370 aluminum alloy. Corrosion tests were performed in solution of 0.1M Na_2SO_4 and 0.001M NaCl. A strong correlation between microstructure and corrosion susceptibility was observed. Due to the presence of Fe-rich phases, galvanic microcells were formed. It leads to the dissolving of aluminum, but there was no noticed relation between Fe-rich intermetallic particles size or distribution and corrosion rate. After metal rework, higher corrosion susceptibility was observed due to smaller grain size, higher misorientation level, and higher grain boundaries density [33].

TABLE 3

Chemical composition of alloys applied in car wires (percentage values) [36-38]

Alloy	Fe	Si	Cu	Zn	Cr	Ti	Mg	Mn	Ga	Al
AW1350	0,19	0,11	0,023	0,038	0,01	0,018	0,021	0,09	—	balanced to 100 (≥99,5)
AW1370	≤0,25	≤0,1	≤0,02	≤0,04	0,01	—	≤0,04	≤0,01	≤0,03	balanced to 100 (≥99,7)
AA 6101 T4	0,13	0,47	0,017	—	—	—	0,48	0,0021	—	balanced to 100

In the paper of R. Gravina et al. focused on corrosion properties of AA1370 as prepared cable and strands [34]. The corrosion behavior of aluminum strand and cable in the solution of 0.1M Na_2SO_4 + 0.001 M NaCl was investigated. There was observed that the cable is more susceptible to corrosion as compared to the strand. In the cable, formation of a high corrosive area occurred due to electrolyte retention in gaps between strands. Also, the galvanic corrosion processes were examined between copper and aluminum joined by ultrasonic welding. It was observed that the dissolution of formed galvanic cells was responsible for dissolving of Al [34].

E. Rhaiem et al. studied the influence of the zincating process on corrosion properties of 6201 aluminum alloy. Corrosion tests of zincated samples showed decreased corrosion process intensity in the aggressive environment of 0.5M NaCl and 0.5M NaCl + 0.1M H_2SO_4. For specific corrosion protection, zincating twice the time was required [35].

The literature review indicates that research of corrosion inhibitors for alloys that find application in car wires manufacturing (1350, 1370, 6101 and 6201) is not sufficiently developed. One of the reasons can be issues related to the application on the surface of cables. The main areas on the cables exposed to the environment, and leads to the corrosion process, are uncovered connections between aluminum and copper. One of the solutions to prevent the galvanic corrosion phenomenon is the application of protective coatings.

4. Conclusions

The above review shows that aluminum finds many applications in the automotive industry, and the crucial role of that material is to provide lighter constructions of cars. Vehicles will be eco-friendly due to limitation of air polutions and have better performance. Aluminum alloys are susceptible to recycling, which is essential after the car's life and leads to a waste limit.

Among reviewed alloys, the easiest for protection are aluminum alloys which find application for car heat exchangers. Application of protective compounds is made by adding to coolant fluid where the circuit is closed. Also, in alloys applied for car bodies and frames, protection is simplified due to applying protective coatings covered by the final painting.

During further research procedures, special attention should be focused on corrosion prevention wide area which is still not investigated is corrosion inhibitors of alloys that find the application on car wires (Al rich alloys: AA1350 nad 1370 and alloys from 6xxx series, e.g., 6101 and 6201).

During exploitation time, wire harnesses are exposed to extreme conditions e.g., high temperature amplitudes or contact with a chemically aggressive environment. Corrosion is an undesired phenomenon which that leads to a decrease of mechanical and electrical parameters of car cables.

Due to specific form, aluminum cables are difficult to protect against corrosion by the use of coatings and there is a risk of deterioration of the electrical properties of the cables. On the other hand, the anti-corrosive protection of the cables should protect the cables throughout the car's lifetime because car harnesses are designed for full lifetime of vehicle. Potential cable failure in the car in worst case may lead to a serious accident on the road.

Therefore, further research should also focus on selecting such inhibitors, the activity of which would protect against corrosion throughout the car's service life, without the need to replenish them. Might protective compounds can be applied on area between cable and insulation or during drawing process in the lubricant.

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