TiMER
Trends in Mechanical Engineering Research

PRINCIPAL MATERIAL RELATIONAL ANALYSIS DUCTING BASED ON THE PRICE AND CORROSION RATE MATERIALS

Raihan Rabby Zahran[a], Sunardi Sunardi[a],* Haryadi Haryadi[a], Mekro Permana Pinem[a], Yusvardi Yusuf[a], Harly Demustila[a], Intan Nazwa[a]

[a] Department of Mechanical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia
*Corresponding author: sunardi@untirta.ac.id

Graphical abstract

Figure 1. Graphical Abstract

Article history
Received
12 June 2024
Received in revised form
22 June 2024
Accepted
25 June 2024
Published
28 June 2024

Abstract

Ducting is a supporting component of the HVAC system. (Heating, Ventilation, and Air Conditioning). In other words, ducting can be used as an air supply, and as a channel for both cold and hot air, air drainage, air absorption, and ventilation. It is used to ensure that the air quality in the room is awakened according to the needs of the room. In the selection of material for ducting, one can consider various aspects. In this journal, the aspects considered are the corrosion rate, ultimate tensile strength, and the material price of the three types of materials, namely BJLS, aluminium, and stainless steel. Based on the results of the test and calculation, BJSL has the highest corrosion rate of about 0.62 Mpy on the 14th day, stainless steel has a corrosive rate of around 0.29 Mpy on the 14th day, and aluminum has the lowest rate of corrosiveness of about 0,27 Mpy at the 15th day.

Keywords: Corrosion; Ducting; Material

Abstrak

Ducting merupakan komponen pendukung sistem HVAC (Heating, Ventilation, and Air Conditioning). Dengan kata lain, ducting dapat digunakan sebagai penyuplai udara, dan sebagai saluran untuk udara dingin maupun panas, pembuangan udara, penyerapan udara, maupun ventilasi. Hal ini digunakan agar kualitas udara yang berada didalam ruangan terjaga sesuai dengan kebutuhan dari ruangan tersebut. Dalam pemilihan material untuk ducting, dapat mempertimbangkan berbagai aspek. Pada jurnal ini, aspek yang dipertimbangkan yaitu tingkat laju korosi, ultimate tensile strength, dan harga material pada 3 jenis material yaitu BJLS, Aluminium, dan Stainless Steel. Berdasarkan hasil pengujian dan perhitungan BJLS memiliki laju korosi yang paling tinggi yaitu sekitar 0,62 Mpy pada hari ke-14, stainless steel memiliki laju korosi sekitar 0,29 Mpy pada hari ke-14, dan aluminium memiliki laju korosi paling rendah sekitar 0,27 Mpy pada hari ke-14. Sedangkan berdasarkan aspek keseluruhan, stainless steel merupakan material yang paling baik digunakan sebagai material utama ducting jika ditinjau dari segi laju korosi, nilai ultimate tensile strength, dan harga.

Kata kunci: Ductingl; Korosi; Material
Doi: http://dx.doi.org/10.62870/timer.v2.i1.26160

1.0 INTRODUCTION

With the advancement of the era, the development that is taking place in the present era is also quite rapid. The construction itself is intended to be able to meet the needs of humans, for example, factories for production, hospitals, and even dwellings like apartments. Every building must have a good and adequate airway. An air conditioning system is a very important thing for indoor use. In an air conditioner system, there is a connection between one component and the other component. These connections are pipe-shaped or more commonly known as ducting.

Ducting is generally made from both metal and non-metallic materials, such as BJLS, aluminum, stainless steel, PVC, etc. Metal materials have the potential to suffer corrosion. Corrosion on ducting can cause serious problems such as leakage or air temperature changes in ductings.

According to Tampubolon, corrosion is a decrease in the quality of metal material due to the presence of electrochemical reactions with the surrounding environment [1]. The corrosion process is generally in the shape of a brown stain that, if left behind, will cause the metal to scratch. This can happen on almost any kind of metal. Corrosion initially occurs slowly, so it can affect the lifespan of the metal used. Corrosion is divided into several types, such as pitting, erosion, uniform corrosion, intergranular, and wild current corrosions [2].

Figure 2. Ducting Corrosion

On ducting, corrosion usually occurs due to the influence of air from inside and outside of the duct. The cold air channelled by the ducting makes it condensate, so these are the water points that will be the root of the corrosion. Corrosion itself is a natural process that can't be prevented, but it can be controlled by reducing the rate of corrosion so that the materials used can last a long time, one of which is by performing corrosion rate testing.

2.0 METHODOLOGY

Corrosion rate testing can be performed using chloride solutions, such as sodium chlorides, hydrogen chlorids, and also other corrosive solutions. Corrosion rate testing itself has many methods, one of which is the weight loss method. Weight loss method is a method of testing the corrosion speed by calculating it through the reduction of the weight of a material or specimen after being submerged in a NaCl solution of 5%. Then after obtaining the difference of the material mass reduction, the further corrosive rate can be calculated using the formula equation found in the ASTM G 31-72 standard.

$$CR = \frac{K \times W}{A \times t \times D}$$

CR : Corrosion Rate (mpy)
K : Corrosion Rate Constant = 3,45 x 106 (mpy)
W : Weight Loss (g)
A : Area (cm^2)
t : Dive Time (Hour)
D : Material Density (g/cm^2)

On corrosion rate testing, there are some steps to take. First the specimen weighs and records its initial mass. Then, the NaCL solution is poured into a 150 mL container. Afterwards, the specimens are soaked in the solution of NaCL in each different container, after a day, the sample is removed and dried. After drying, the samples are weighed to determine their mass after soaking. Subsequently, the specimens are re-immersed, and mass weighing is done every 24 hours for two weeks.

The type of ducting used in the material price comparison is using the type of round duct. A round duct is a cylinder-shaped duct that has a lower pressure drop compared to other ducting types, but it is more expensive because it is more difficult to produce. [3]

However, there are some materials used in the comparison of the main material of the ducting this time, namely:

1. BJLS is a steel material that is coated by zinc or zinc with a certain thickness. As with the BJLS with the mass symbol Z20 has a nominal thickness of base metal which is about 0.6 to 1 mm. The Z20 is a low-carbon steel that has a thickity of 1 mm with a unit mass after coating about 8.135 kg/m2. The composition of the mass unit of carbon steel metal is about 96.4% (7.85 kg/ m2) and the thick zinc coating is about 3.5% (0.285kg/m2) [4]

2. Aluminium is a metal that has a fairly good strength, but has a light weight or mass. In addition, aluminium has quite good corrosion resistance and strength, making it one of the ducting materials options on HVAC systems [5]. Aluminium has its type or series based on its level of purity. The 1000 series aluminium is pure aluminium with a purity of 90%. This aluminium has a density of approximately 2720 kg/m3 [6]. In addition to the 1000 series of aluminium, there are other series such as the 3000 series of aluminium with the addition of Mn or maganese to increase

the corrosion resistance and melting point of the aluminum alloy. Aluminium series 2000 with copper addition which has hard and strong properties, but is corrosive and fragile. Aluminium series 5000 with magnesium addition which is strong against marine water corrosion as well as low temperatures. Aluminium Series 6000 has silicone magnesia addition that has corrosive properties and sufficient strength. Aluminum series 7000 with zinc addition has the highest strength of other aluminum series [7].

3. Stainless steel is a metal that has a high resistance to corrosion from moisture and most chemicals. As a result, stainless Steel has become one of the most commonly used materials in the production of ducting, especially for types 304 and 316. 304 series of stains contains 71.4% of Iron (Fe), 7.99% of Nickel (Ni), 17.93% of Chromium (Cr), 1.40% of Manganese (Mn), 0.10% of Molybdenum (Mo), 0.003% of Aluminium (Al), 0.05% of Carbon (C) and 0.006% of Sulphur (S) [8]. Stainless steel series 304 has a density of about 7900 kg/m^3 [6].

3.0 RESULTS AND DISCUSSION

3.1 DUCTING CORROSION RATE

The materials used in the test were BJLS Z20, aluminum 1100, and 304 stainless steel. Before doing the test, each specimen was measured both in length, width, and thickness. Once the dimensions are known, each material is calculated its surface area to be used in the calculation of the corrosion rate.

Table 1. Specimen Measurement

Materials	Density (g/cm^3)	Length (cm)	Width (cm)	Thickness (cm)	Area (c
BJLS	7,85	3,7	3,5	0,1	27
Aluminium	2,72	3,7	3,5	0,1	27
Stainless Steel	7,9	3,7	3,5	0,05	26

After the measurement, each specimen is placed in a separate container and submerged with a 5% NaCl solution of 150 mL. Submergence is carried out for 2 weeks, with the weight of the specimen being checked every 1 day.

Table 2. Weight Loss Materials

Days	Weight of Materials (g)		
	BJLS	Aluminium	Stainless Steel
0	10,240	3,550	6,190
1	10,232	3,550	6,186
2	10,232	3,550	6,185
3	10,233	3,551	6,184
4	10,232	3,549	6,184
5	10,231	3,549	6,183
6	10,230	3,549	6,183
7	10,229	3,548	6,183
8	10,228	3,548	6,184
9	10,228	3,548	6,183
10	10,228	3,548	6,183
11	10,228	3,548	6,184
12	10,228	3,548	6,184
13	10,227	3,548	6,184
14	10,227	3,548	6,184

Table 3. Corrosion Rate Materials

Time (Hour)	Corrosion Rate (mpy)		
	BJLS	Aluminium	Stainless Steel
24	5,358	0,000	2,734
48	2,679	0,000	1,709
72	1,563	-0,644	1,367
96	1,340	0,483	1,025
120	1,206	0,387	0,957
144	1,005	0,322	0,797
168	0,957	0,522	0,684
192	0,921	0,483	0,513
216	0,893	0,430	0,532
240	0,804	0,387	0,478
264	0,731	0,351	0,373
288	0,670	0,322	0,342
312	0,670	0,297	0,315
336	0,622	0,276	0,293

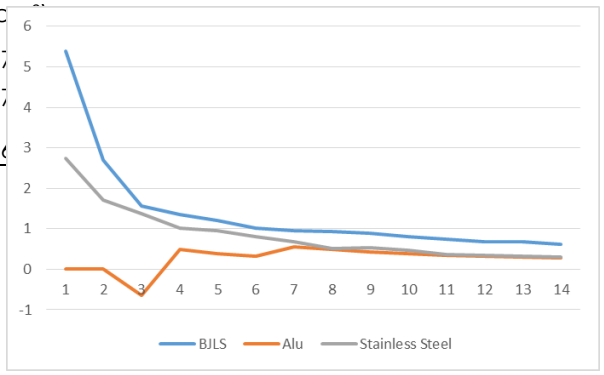

Figure 3. Ducting Corrosion

BJLS has the highest corrosion rate of about 0.62 Mpy on the 14th day, stainless steel has a corrosions rate of approximately 0.29 Mpy in the 14 th day, and aluminium has a lowest Corrosion Rate of around 0.27 Mpy at the 13th day. From this comparison it can be seen that aluminium and steel have no very different corrosional rates. This is because both these materials have a fairly high corrosive resistance.

BJLS Z20 is a low-carbon steel with a thickness of 1 mm with a unit mass after coating of approximately 8,135 kg/m2. (BSN, 2006). Based on the corrosion rate chart that can be seen on the BJLS, the first day's rate values tend to be high, but as time passes, the rate value decreases. According to Santoso in his journal, this can happen because, in the initial conditions, carbon steels will react spontaneously, but over time, the zinc layer will form an oxide compound named zinc hydroxide Zn(OH)2, which is a passive layer as a protector of the low carbon steel substrate [9].

Aluminum 1100 is a 1000-series aluminum that has a purity of aluminum above 90%. On the graph, aluminum has experienced a decrease in its corrosion rate. After decreasing, the corrosion rate of the aluminum will be stable. According to Rohadi Satrio Utomo, this can happen because of the oxide layer formed by the oxidation reaction. The increase in the mass of aluminum occurs because aluminum reacts with the solution and creates aluminum oxide (Al2O3). Aluminum oxide is a thin layer that adheres very strongly to the surface and serves to protect aluminum from corrosion attacks. The aluminum oxide layer is stable in an environment of pH 4 s/d pH 9, which is what makes the corrosion rate chart on aluminum tend to be stable because the solution used for this corrosive test is salt with a pH of 7 [10].

304 stainless steel is a type of steel that contains 71.4% of iron (Fe), 7.99% of nickel (Ni), 17.93% of chromium (Cr), 1.40% of manganese (Mn), 0.10% of molybdenum (Mo), 0.003% of aluminium (Al), 0.05% of carbon (C) and 0.06% of sulfur (S) [8]. As can be seen in the graph, stainless steel has a corrosion rate that tends to decrease drastically in the early days, then will tend to remain stable until the 14th day. According to Sinta Novita in her journal, this may be due to the iron (Fe), carbon (C), and sulfur (S) content that makes stainly steel have a high corrosive rate at the beginning of the submersion. However, stainless steel has other elements that can prevent corrosion such as nickel (Ni), manganese (Mn), molybdenum (Mo), aluminium (Al), and chromium (Cr). According to him, the high carbon content (C) allows for the formation of chrome carbide (CRC) at the boundary of the grain, thereby reducing the concentration of chroma (CR) at its boundaries, thus facilitating the rate of corruption. In addition, stainless steel also produces a passive layer of chromium oxide (Cr2O3) that has protective and stable properties to protect stainly steel from corrosion [8].

3.2 DUCTING PRICE

After comparing the corrosion rate of the material, the next is the price comparison of each used material. The price to make a ducting is usually calculated based on the weight of the per-kilogram. On the market, the material is usually sold in a sheet shape with a size of 1.22 x 2.44 m with a thickness of 1 mm. Weight references and the price of the sheet material are obtained based on the marketplace and interviews.

Table 4. Materials Price list

Materials	Weight per-sheet (kg)	Price per-sheet	Price per-kilogram
BJLS	23,33	Rp798.665,00	Rp34.250,00
Aluminium	8,60	Rp686.000,00	Rp79.800,00
Stainsless Steel	23,60	Rp1.278.400,00	Rp54.200,00

In the manufacture of ducting, there are many sizes that can be made according to needs. One in the manufacture of round ducts or round ducting can be made with different diameters, as to make a round duck with a hole diameter of 500 mm requires a material plate with a length of 1220 mm, a width of 1600 mm, and a thickness of 1 mm. Thus, to obtain the mass of a round conductor with a diameter 500 mm can use the equation of the following specific weight.

$$\gamma = \frac{w}{v}$$

γ : *Spesific Weight* (kg/m^3)

W : Weight (kg)

V : Volume (m^3)

Table 5. Materials Spesification for Round Duct

Materials	Spesific Wight (km/m^3)	Volume (m^3)	Weight (kg)
BJLS	7837	0,001952	15,30
Aluminium	2889	0,001952	5,64
Stainsless Steel	7928	0,001952	15,48

The next step is to calculate the price based on the weight obtained to make one round duct.

Table 6. 500 mm Round Duct Price

Materials	Weight (kg)	Price per-kilogram	Round Duct Price
BJLS	15,30	Rp34.250,00	Rp524.000,00
Aluminium	5,64	Rp79.800,00	Rp450.000,00
Stainsless Steel	15,48	Rp54.200,00	Rp838.300,00

3.3 ULTIMATE TENSILE STRENGTH

Ultimate tensile strength or UTS is a mechanical property that measures the maximum voltage that a material can hold before it fails or breaks due to traction. In ducting, the UTS is an important parameter used to assess the strength and durability of the material to withstand the deformation that occurs when the ducts are presented vertically or horizontally. Based on the book mechanics of materials by Ferdinand Beer and AISI 304, the ultimate tensile strength values of BJLS, aluminum, and stainless steel materials are known [11].

Table 7. Ultimate Tensile Strength

Materials	Ultimate Tensile Strength (Mpa)
BJLS	400
Aluminium	110
Stainless Steel	505

3.4 Optimization Value

The performance optimization of the main ducting material can be determined by comparing the corrosion rate, the ultimate tensile strength, and the price of the BJLS, aluminum, and stainless steel materials. The values required to calculate the optimization are as follows.

Table 8. Corrosion Rate, UTS, Round Duct Price

Materials	Corrosion Rate (mpy)	Ultimate Tensile Strength (Mpa)	Round Duct Price
BJLS	0,622	400	Rp524.000,00
Aluminium	0,276	110	Rp450.000,00
Stainless Steel	0,293	505	Rp838.300,00

Based on the data, the lowest value of the corrosion rate and the price of the round duct will be divided by the value and price of each material. In contrast, the value of the ultimate tensile strength itself is slightly reversed; that is, the material's UTS value is divided by the highest UTS. Then, the values of such materials can be multiplied to result in total optimization of the material. The material with the highest total value is the material that has the best optimization value. As for the calculation of the optimization value is as follows.

Table 9. Optimization Value Materials

Materials	Corrosion Rate	Ultimate Tensile Strength	Price	Optimation
BJLS	0,444	0,792	0,859	0,302
Aluminium	1,000	0,218	1,000	0,218
Stainsless Steel	0,942	1,000	0,537	0,506

4.0 CONCLUSION

Based on the report that has been prepared from the beginning to the conclusion, there are two things that can be concluded as follows.

1. It can be concluded that, BJLS has the highest corrosion rate of about 0.62 Mpy on the 14th day, stainless steel has a corrosions rate of around 0.29 Mpy at the 14 th day, and aluminium has the lowest corrosion rate of approximately 0.27 Mpy in the 14h day.
2. Based on the material performance optimization values, stainless steel has the highest optimization value, while aluminum has the lowest optimization value. Thus, it can be concluded that stainless steel is the best material used as the main ducting material when reviewed in terms of corrosion rate, ultimate tensile strength, and price.

Acknowledgment

This research is independent work. The authors fully acknowledged to Mechanical Engineering Dept, Sultan Ageng Tirtayasa University.

References

[1] Tampubolon, M. G. (2020). Laju Korosi Pada Baja Karbon Sedang Akibat Proses Pencelupan Pada Larutan Asam Sulfat (H2SO4) dan Asam Klorida (HCl) dengan Waktu Bervariasi. *SJoME Vol. 2 No. 1*, 13-14.

[2] Pattireuw, K. J. (2013). Analisis Laju Korosi pada Baja Karbon dengan Menggunakan Air Laut dan H2S04. 2.

[3] Asep Fathudin, A. U. (2020). Analisa Desain Ducting Saluran Outpt By-Pass pada Blower Exhaust Fan EF 08/09 Fasilitas Radiometalurgi. *ISSN 1979-2409*, 29-30.

[4] BSN. (2006). *Baja Lapis Seng SNI 07-2053-2006*. Indonesia: Badan Standardisasi Nasional.

[5] Haryanto, M. R. (2019). Perencanaan Ducting pada Gedung Serbaguna Desa Lumpatan 1. *Jurnal PETRA Vol 6, No 1*, 1-7.

[6] Cengel, Y. A. (2002). *Heat Transfer A Practical Approach*. New York: Mcgraw-Hill.

[7] Sarkepo. (2021, Juni). *9 Jenis Aluminium Beserta Fungsinya*. Retrieved from Sarkepo.com: https://sarkepo.com/jenis-jenis-aluminium/.

[8] Novita, S. G. (2018). Analisis Laju Korosi dan Kekerasan pada *Stainless Steel* 304 dan Baja Nikel Laterit dengan Variasi Kadar Ni (0,3 dan 10%) Dalam Medium Korosif. *JURNAL Teori dan Aplikasi Fisika Vol. 06 No.01*, 21-31.

[9] Santoso, A. H. (2015). Pengaruh Beban Terhadap Laju Korosi Lapisan Baja Galvanum (Zn55Al) Di Lingkungan Air Ledeng dan Air Laut. *JURNAL TEKNIK ITS Vol. 4, No. 1*, 1-5.

[10] Utomo, R. S. (2017). Studi dan Karakterisasi Laju Korosi Logam Aluminium Dengan Pelapisan Membran Sol-Gel. *Jurnal Teknik Mesin Vol. 06, No.3*, 191.

[11] Beer, F. E. (2013). *Mechanics of Materials*. New York: McGraw Hill Eduction.