Jurnal Rekayasa Mesin
p-ISSN: 1411-6863, e-ISSN: 2540-7678
Vol.20, No.3, Desember **2025**, hal.475-482

Design of Jominy Hardenability Testing Equipment in Accordance with ASTM A255 Standard

Rizky Muhammad Isdy*, R. Faiz Listyanda, M. Fendy Kussuma Hadi Sufyan, Her Tafga Arfanindita, Ikhwan Taufik[5]
Departement of Mechanical and Industry Engineering, Departement of Engineering, Tidar University,
39 Kapten Suparman Street, Potrobangsan, North Magelang 56116, Central Java, Indonesia
*E-mail: rizkyisdy@gmail.com

Submitted: 07-11-2025; Accepted: 03-12-2025; Published: 30-12-2025

Abstract

This study discusses the design and development of a Jominy Hardenability Test apparatus based on the ASTM A255 standard, which is used to determine the hardenability of metallic materials, particularly steel. The purpose of this research is to produce a Jominy testing device that meets standard specifications, perform structural analysis using CAD Software, and evaluate the functional performance of the manufactured tool. The research method consists of several stages, including 3D design using CAD Software, structural analysis simulation with the Finite Element Analysis (FEA) method covering von Mises stress, displacement, and safety factor, followed by the manufacturing process according to the design results. The simulation results show a maximum stress of 2.039 × 10^6 *N/m², a maximum displacement of 5.8 ×* 10^{-1} *mm, and a safety factor value of 2.6, indicating that the design is structurally safe for production. The manufacturing process uses galvanized as the frame, body material and includes an additional cooling fan to maintain water temperature stability during the quenching process. The functional test results show that the tool can perform quenching effectively, producing a maximum hardness value of 370 VHN and a minimum value of 280 VHN on the steel specimen. This research is expected to contribute as a reference for the development of economical, efficient, and standard ASTM A255 compliant Jominy testing equipment for researh and development.*

Keywords*: ASTM A255; CAD software; hardenability; Jominy test; tool design*

Abstrak

Penelitian ini membahas tentang perancangan dan pembuatan alat uji Jominy Hardenability Test berdasarkan standar ASTM A255 yang digunakan untuk mengetahui kemampuan pengerasan (*hardenability*) suatu material logam, khususnya baja. Tujuan dari penelitian ini adalah untuk menghasilkan rancangan alat uji jominy yang sesuai standar, melakukan analisis struktur menggunakan perangkat lunak CAD, dan mengetahui hasil uji fungsi alat setelah proses manufaktur. Metode penelitian dilakukan melalui beberapa tahapan, yaitu perancangan desain 3D dengan CAD software, simulasi analisis struktur menggunakan metode *Finite Element Analysis* (FEA) meliputi von Mises stress, displacement, dan safety factor, serta pembuatan alat sesuai hasil desain. Hasil simulasi menunjukkan nilai tegangan maksimum sebesar 2.039 × 10^6 N/m², displacement maksimum sebesar 5,8 × 10^{-1} mm, dan nilai safety factor sebesar 2,6, yang menunjukkan bahwa desain alat aman untuk diproduksi. Proses manufaktur dilakukan dengan pemilihan material rangka, body dari galvanis serta penambahan kipas pendingin untuk menjaga stabilitas suhu air selama proses quenching. Uji fungsi menunjukkan bahwa alat mampu melakukan proses quenching dengan baik, menghasilkan nilai kekerasan tertinggi sebesar 370 VHN dan terendah sebesar 280 VHN pada spesimen baja. Hasil penelitian ini diharapkan dapat menjadi referensi dalam pengembangan alat uji jominy yang lebih ekonomis, efisien, dan sesuai standar ASTM A255 untuk penelitian dan pengembangan.

Kata kunci: ASTM A255; CAD *software*; desain alat; *hardenability*; uji *jominy*

1. Introduction

The advancement of manufacturing technology, automation, and materials engineering demands a material testing system that is fast, efficient, and accurate [1] . One of the most important properties of metals is hardenability, which refers to the ability of a material to undergo hardening to a certain depth as a result of heat treatment. The microstructural transformation from austenite to martensite increases the hardness and wear resistance of machine components.

The Jominy test, according to ASTM A255 standards, is widely used to determine the hardenability of steel by heating a cylindrical specimen and cooling it only at one end with a jet of water. The standard specimen dimensions are 100 mm in length and 25 mm in diameter, with a nozzle diameter of 12.7 mm and a distance of 12.7 mm between the specimen end and the nozzle [2]. The frame, specimen holder, and body of the device are made of galvanized material, while the water tank is made of plastic. The equipment is also equipped with a quenching tank designed to prevent water splashing and ensure that the specimen is precisely positioned above the nozzle [3]. The validity of test results highly depends on the precision of specimen positioning, the stability of cooling flow rate and temperature, and the consistency of the quenching system [4]. The development of an ergonomically designed, affordable, and easy-to-operate device makes this design applicable and potentially producible on a wider scale, fulfilling an important need in the field of material testing. A device that meets the standards is crucial to ensure that the obtained test results are accurate, valid, and applicable [5].

However, not all educational institutions possess a Jominy testing apparatus that meets ASTM A255 standards due to its high cost and complex design. Most previous studies have focused more on the effects of heat treatment parameters (temperature, holding time, and quenching medium) on material hardness, without addressing the detailed engineering design of the Jominy apparatus [6]. This gap highlights the need for the development of an economical, ergonomic, and technically standardized Jominy testing device, including innovations in the cooling system such as the addition of a fan to accelerate heat dissipation from the quenching medium and maintain the water temperature stability. Therefore, this study aims to design, analyze, manufacture, and test a Jominy testing apparatus in accordance with ASTM A255 standards.

2. Material and Method

This study uses a Jominy test device that functions to perform rapid cooling (quenching) after heat treatment. The Jominy end-quench method is used to measure the distribution of steel hardness values after the hardening process, so that the hardenability of the material can be determined [7]. During the testing stage, cylindrical steel specimens are heated to austenitizing temperature, which is the condition when steel is in the austenite phase [8] and then held for a certain period of time. Next, one end of the specimen is cooled using a water jet through a nozzle, resulting in a difference in the cooling rate along the length of the specimen [9] The rapid cooling process (quenching) is sudden cooling after heat treatment using a specific cooling medium in accordance with the characteristics of the material [4]. The Jominy test apparatus was designed using Computer Aided Design (CAD) software [10]. The design of the Jominy Hardenability test apparatus refers to the ASTM A255 standard, with specimen dimensions of 100 mm in length and 25 mm in diameter. A cooling nozzle with a diameter of 12.7 mm is placed at a distance of 12.7 mm from the end of the specimen to ensure an even flow of cooling water during the testing process [11]. The frame, specimen holder, and body of the device are made of galvanized material, while the water tank is made of plastic. The water nozzle container is made of AISI 304 stainless steel because it has good corrosion resistance[12]. Galvanized material is steel or iron coated with zinc through a galvanization process, generally using the hot-dip galvanizing (HDG) method [13]. In addition, the testing device is equipped with a fan that serves to increase air circulation and help maintain water temperature stability during the testing process [14,15]. This research was conducted from July to October 2025 at the Mechanical Engineering Laboratory of Tidar University, which was chosen because it has adequate infrastructure for the design, manufacturing, and testing processes. The equipment used included welding equipment, hand tools, heating furnaces, Jominy test equipment, and laptops for data processing. The tool design process followed the Pahl and Beitz design methodology, which consists of the planning, conceptual design, form design, and detailed design stages [16]. Structural strength analysis was performed using the Finite Element Analysis (FEA) method to evaluate the structure's response to working loads [17,18]. The analysis parameters used included stress analysis, displacement, and safety factor [19,20].

3. Results and Discussion

3.1. Results of Structural Analysis

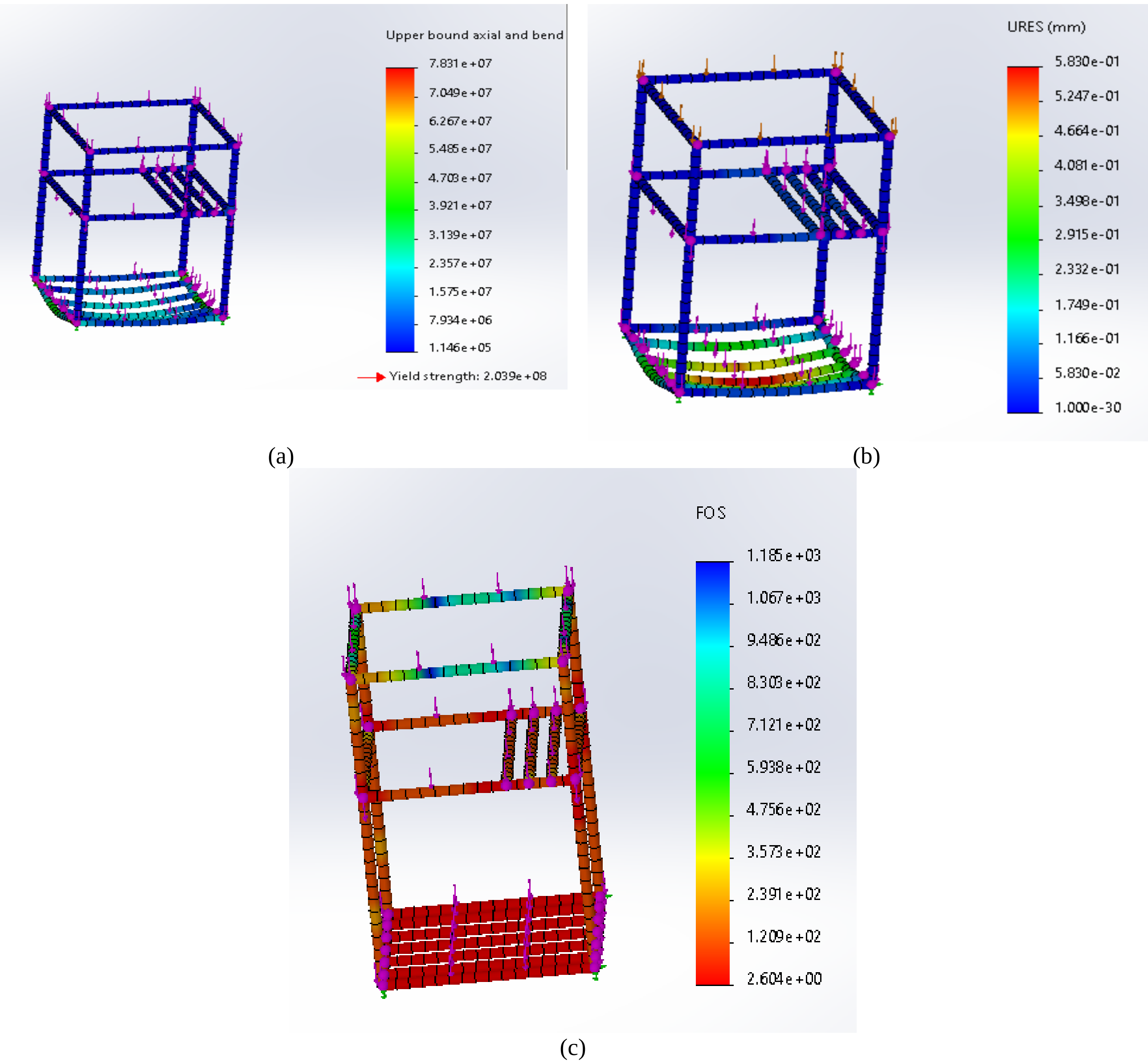


Figure 1. Results of analysis: (a) Structural stress, (b) Displacement, (c) Safety factor

Based on tests conducted on the Jominy test apparatus, the load is located at the purple downward arrow and the loading point at the end of the frame at the circular purple weld joint using a solid mesh. Solid mesh divides the model volume into small particles. The Finite Element Analysis (FEA) results show that the maximum stress on the frame is 2.039×10^6 N/m^2, whileBased on tests conducted on the Jominy test apparatus, the load is located at the purple downward arrow and the loading point at the end of the frame at the circular purple weld joint using a solid mesh. Solid mesh divides the model volume into small particles. The process of collecting data from Finite Element Analysis (FEA) is the selection of materials, the provision of fulcrums, namely for load points on the frame, then the load points to apply the load to the frame, followed by the meshing process, which divides the model volume into small particles, and then the simulation run process to show the simulation results with a maximum frame stress value of 2.039×10^6 N/m², while the minimum stress is 1.146×10^5 N/m². The maximum displacement obtained is 0.58 mm, which is still within the permissible tolerance limit. In addition, the structure is capable of withstanding the applied load with a minimum safety factor of 2.6. These findings indicate that the structural design is feasible and safe for the manufacturing process.

3.2. Design of the Apparatus

The design of the Jominy testing apparatus was created using CAD software. This design represents an assembly composed of several interconnected parts. The isometric view of the Jominy test apparatus design can be seen in Figure 2.

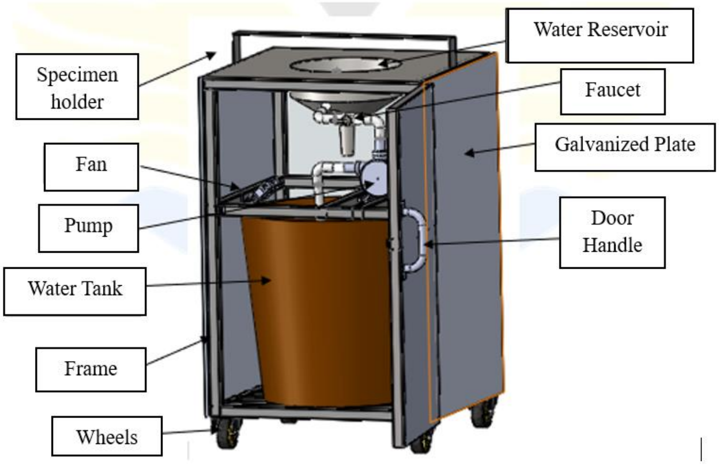


Figure 2. Jominy Test Apparatus

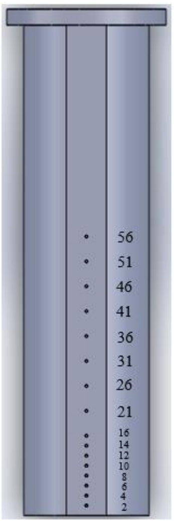
The design of the Jominy test apparatus consists of several components. These components, which are include in the apparatus design and fabrication process, are listed in Table 1.

Table 1. Components required for the design of the Jominy test apparatus

Component	Quantity	Specification
Water pump	1	125 W, 30 L/min
Specimen holder/support	1	Length = 600 mm, Width = 100 mm
Axial fan	3	Length = 90 mm, Width = 90 mm
Water tank	1	Diameter = 500 mm, Height = 500 mm
PVC pipe ½"	1	Outer diameter = 25 mm, Inner diameter = 22 mm
Stop valve ½"	1	Outer diameter = 28 mm, Inner diameter = 25 mm
Stainless steel plate	1	Length = 1.2 m, Width = 1 m
Galvanized plate	1	Length = 2 m, Width = 900 mm
90° pipe elbow	4	Length = 50 mm, Diameter = 25 mm

3.3. Test Results

The experimental test was carried out using ST 37 steel specimens, followed by a heat treatment process using a furnace at a temperature of 800°C with a holding time of 52 minutes. After the heat treatment, the specimen was placed on the Jominy test apparatus for the quenching process, which was performed for 15 minutes. After the quenching process, hardness testing was conducted using the Vickers hardness tester at several measurement points as shown in Figure 3.



(a)

(b)

Figure 3. Jominy specimen: (a) design, (b) actual specimen

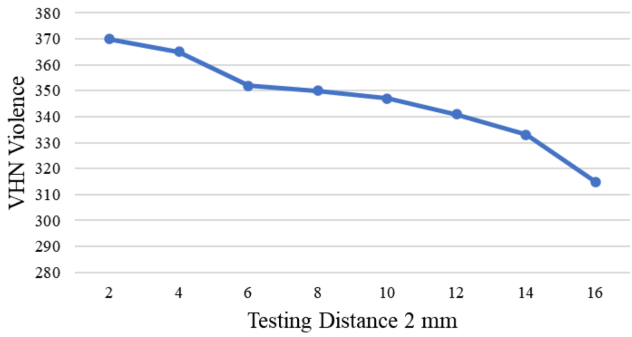
Table 2. Vickers Test Results

No	Specimen		Diagonal (mm) D1	D2	Avarage Diagonal (ɥm)	VHN Violance
1	ST 37, Testing Distance: 2 mm	2	35,40	35,40	35,40	370
		4	35,65	35.65	35.65	365
		6	36,30	36,30	36,30	352
		8	35,96	36,84	36,40	350
		10	36,58	36,58	36,58	347
		12	36,33	37,39	36,88	341
		14	37,31	37,31	37,31	333
		16	38,68	38,10	38,39	315
2	ST 37, Testing Distance: 5 mm	20	38,54	38,54	38,54	311
		26	39,89	38,30	39,095	303
		31	38,88	39.79	39.79	300
		36	39,92	39,38	39,65	295
		41	39,60	40,62	40,11	288
		46	38,92	41,36	40,14	288
		51	40,56	39,82	40,19	287
		56	40,87	40,48	40,67	280

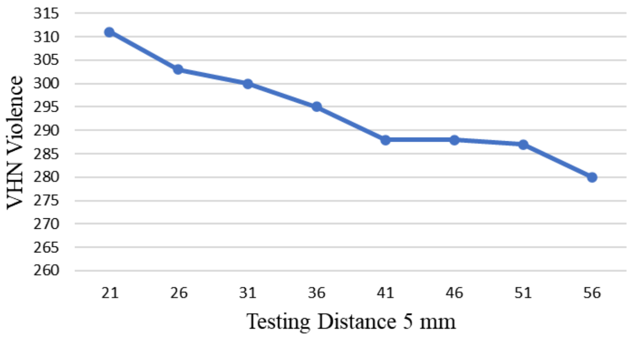
To determine the hardness value of the specimen after *the* quenching process, testing was conducted using the Vickers Hardness Test (VHN) method. This method was chosen because it provides accurate measurement results on steel surfaces with varying hardness levels. The test was carried out by applying a specific load on the surface of the specimen.

The Vickers hardness value can be calculated using the following equation:

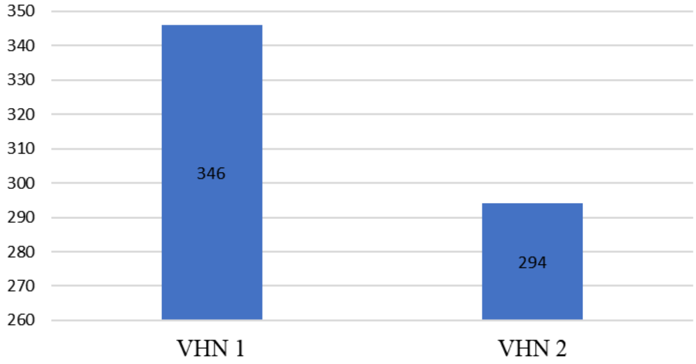
Calculation: $HVN = 1.854 \times \frac{P}{d^2}$ ………………………………………………………………………………………..(1)



(a)



(b)



(c)

Figure 4. (a) Vickers Hardness Test Results Graph I (b) Vickers Hardness Test Results Graph II (c) Comparison of Average Vickers Hardness Test Graph

The test results show that the Vickers hardness value gradually decreases with increasing distance from the cooling tip. This pattern is consistent with the Jominy curve for low carbon steel reported in the literature, where steel equivalent to ST 37 or AISI 1018/1020 shows a rapid decrease in hardness due to low carbon content. The closeness of the hardness values and the conformity of the hardening curve trends indicate that the developed Jominy test apparatus is capable of producing accurate and reproducible test results.

The Vickers hardness test results in Figure 4 show the hardness values at each testing distance from the quenched end of the specimen. To observe the variation of hardness with distance, the data are presented in graphical form as shown in Figure 5.

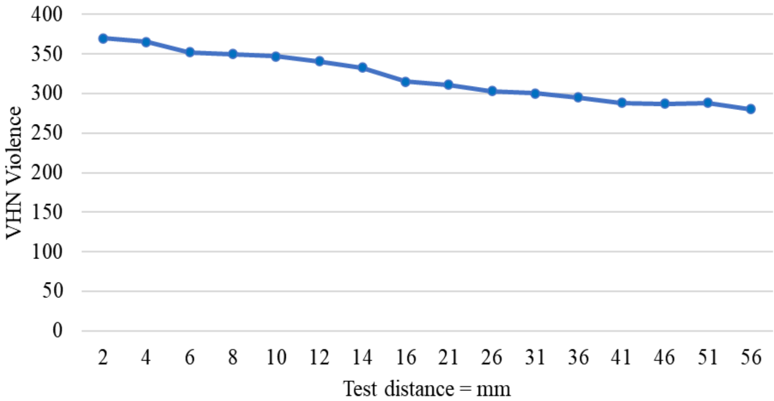


Figure 5. Vickers Hardness Test Graph

The graph above shows the results of the Vickers hardness test on the specimen tested using the Jominy test method. From the graph, it can be observed that the highest hardness value is located at the quenched end of the specimen, at a testing distance of 2 mm from the end, with a value of approximately 370 VHN. The hardness then gradually decreases as the distance from the quenched end increases, reaching around 280 VHN at a distance of 56 mm. This decrease indicates that the water quenching at the end of the specimen produced a high cooling rate, resulting in the formation of a hard martensitic structure near the quenched end. In contrast, the regions farther from the quenched end experienced a slower cooling rate, leading to the formation of pearlitic structures, which exhibit lower hardness values.

4. Conclusion

Based on design analysis using CAD software, the results show a maximum stress of 2.039×10^6 N/m², a maximum displacement of 0.58 mm, and a safety factor of 2.6. Therefore, the manufacture of the Jominy test rig frame is considered structurally safe for production. The manufacturing process was carried out in accordance with the design specifications, with tool dimensions of 900 × 600 mm, a water tank capacity of 73.27 liters, a water flow of 328 m/s, a water pressure of 40 psi, and a fan-powered cooling system to maintain a stable water temperature during the cooling process. Functional testing showed that the device operates effectively, maintaining a stable cooling temperature in the range of 20°C - 24°C, and producing specimen hardness values ranging from 370 VHN (maximum) to 280 VHN (minimum). FEA simulation results on the upper frame with a load of 19.6 N, the middle frame with a load of 78 N, and the lower frame with a load of 277 N with a safety factor of 2.6 show that the Jominy test device is safe for manufacturing and can function reliably and meet the required hardness test standards.

Acknowledgement

The authors would like to express their gratitude to the Departement of Mechanical and Industrial Engineering, Tidar University, for providing laboratory access and institutional support that facilitated this research.

References

[1] Yasrizal AY. Perancangan dan Pembuatan Alat Jominy Test Standar ASTM A 255-2 dengan Material Uji Baja Karbon Sedang AISI 1045. Universitas Lampung; 2019.

[2] ASTM International. Standards ASTM A255-02. ASTM Int. :1–10.

[3] Nurrohman A, Mulyanto T. Rancang Bangun Alat Uji Jominy Dengan Standar ASTM A255. J METTEK. 2021;7(2):66–72.

[4] Irawan I, Pramudia M, Harofah B. Design Of Semi Automatic Jominy Test For Metal Hardness Testing Practice. Int J Sci Eng Inf Technol. 2024;09(01):518–21.

[5] Rahman, Arif Z, Suheri, Widodo SB. Innovative Jominy Test Equipment for Evaluating The Hardening Behavior of AISI 1045 Steel. Jurutera. 2024;11(02):107–14.

[6] Pratama H, Rahman A, Putra R. Herianto Pratama. Politeknik Negeri Ujung Padang; 2020.

[7] William D.Callister J, Rethwisch DG. Materials Science and Engineering an Introduction. Eighth Edi. John Wiley & Sons, Inc.; 2010. 425–436 p.

[8] Pramono C. Material Teknik. Yogyakarta: Anom Pustaka; 2020.

[9] Priyanto K, Palmiyanto MH, Priyambodo BH. Studi Variasi Temperatur Hardening terhadap Kekerasan Baja AISI 4340 melalui Jominy Test. J Tek. 2023;8(1):1–8.

[10] Planchard DC. SOLIDWORKS 2020 Tutorial A Step-by-Step Project Based Approach Utilizing 3D Modeling-SDC Publications (2020). Stephen Schroff; 2020. 1–643 p.

[11] ASTM International. Standard Test Methods for Determining Hardenability of Steel 1. :1–26.

[12] Susanto H, Supardi J, Sayuthi T, Marliadi H. Rancang Bangun Alat Uji Jominy (Jominy Hardenability Test). Jurnal Mekanova. 2016;2(3):97–107.

[13] Futtsu KNFKTFYSFMN. United States Patent. Materal, Galvaniz Steel Nakazawa, Makoto Jp, Futtsu. 2014;2(12):1–21.

[14] Jatmiko S, Ranto, Karno. Pengaruh Variasi Jumlah Bilah Kipas Pendingin dan Jarak Pemasangan Radiator terhadap Temperatur Air Radiator pada Mesin Suzuki Katana. In Semarang; 2020. p. 872–6.

[15] Machrudin MA, Winardi S, Tristianto D. Sistem Pendingin Aquarium dan Pemantau Suhu Air Berbasis IOT dengan Protokol MQTT. J Sist Cerdas dan Rekayasa. 2023;5(2):1–7.

[16] Beitz GP and W. Engineering Design A Systematic Approach. Wallace K, editor. Springer; 2016. 1–544 p.
[17] Sanjaya DD, Sujiatanti SH, Yulianto T. Analisis Kekuatan Konstruksi Wing Tank Kapal Tanker Menggunakan Metode Elemen Hingga. J Tek ITS. 2017;6(2):277–81.
[18] Abbas H, Juma D. Analisis Pembebanan Rangka Chassis Mobil Model Tubular Space Frame. J Teknol. 2020;15:96–102.
[19] Agus IN, Saputra A, Dantes KR, Nugraha INP. Analisis Tegangan Statik pada Rancangan Frame Mobil Listrik Analisis Tegangan Statik pada Rancangan Frame Mobil Listrik Ganesha Sakti (Gaski) Menggunakan Software Solidworks 2014. J Pendidik Tek Mesin Undiksha. 2018;6(2):113–20.
[20] Sandy Suryady, Eko Aprianto Nugroho. Simulasi Faktor Keamanadan Pembebanan Statik Rangka Pada Turbin Angin Savonius. J Ilm Multidisiplin. 2022;1(2):42–8.