THE STUDY OF THE PHYSICAL AND MECHANICAL PROPERTIES OF MATERIALS RAILROADS

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Abstract. This research is to determine the quality of the railway. As the object of research in this occasion was the train tracks acquired from the workshop of PT. Kereta Api Indonesia. As for the quality evaluation performed include hardness testing, testing of composition, tensile test and microstructure observation. After the base material subjected to the preliminary work, such as the manufacture of test specimens, prepared and then the specimens tested with testing tools for testing the hardness, chemical composition testing, tensile testing and testing microstructure. From the test results obtained with the price average hardness of the railroad is 281.7 HVN. The price of the average composition of the railroads alone amounted to 588.4%, while the average tensile strength of the railroad tracks of 0.04 N/mm², micro structure photograph taken with magnification 100x and 200x. From the test results note that the railroads have high ductility and toughness.
Keywords. Physical, Mechanical, Railways, Microstructure

Abstrak. *Penelitian ini adalah untuk menentukan kualitas bahan pada kereta api. Sebagai objek penelitian dalam kesempatan ini adalah rel kereta api yang diperoleh dari workshop PT. Kereta Api Indonesia. Adapun evaluasi kualitas dilakukan meliputi pengujian kekerasan, pengujian komposisi, uji tarik dan pengamatan struktur mikro. Setelah bahan dasar diberikan pengerjaan awal, seperti pembuatan benda uji, disiapkan dan kemudian spesimen diuji dengan alat uji untuk menguji kekerasan, kimia pengujian komposisi, uji tarik dan pengujian struktur mikro. Dari hasil pengujian diperoleh nilai rata-rata kekerasan rel kereta api adalah 281,7 HVN. Nilai komposisi rata-rata pada rel kereta api sebesar 588,4%, sedangkan kekuatan tarik rata-rata rel kereta api dari 0,04 N/mm², foto struktur mikro yang diambil dengan pembesaran 100x dan 200x. Dari hasil pengujian didapatkan bahwa bahan rel kereta api memiliki keuletan dan ketangguhan yang tinggi.*
Kata kunci. *Fisik, Mekanis, Rel, Struktur mikro*

Introduction

At this time the means of transport is very important in our lives. Transport is fast, secure and convenient always been a desire of the community. And it can be found in railway transportation. Right now the train is a means of transportation that is in demand by the public, in addition to the factor of fast, safe and convenient use of the railway is also considered the most economical.

The train tracks are a critical component in the operation of a train, without a foundation of steel a train cannot function. Indonesia as the country's rail transport users do not have the industry that produces railroad. Businesses no one has made the industry because it has not received assurance regarding the continuity of railway construction.

The impact of the import dependence and improving the quality of existing rail could still be thorough. Currently there are many railroads in Indonesia, the Dutch heritage with the specifications had been longer.

Railroad relic of the Netherlands, has a specification R33 or rails that each piece weighs 33 kg. This rail has a relatively small size, so it cannot be used for high-speed trains. This time it took a rail with higher specifications required is a rail with R54 specifications that each piece weighs 54 kg .

The existence of the railway accident scene did not reduce the public response and even train users increasingly demand. Because the government is trying to fix the rail transportation services in particular so that the things that are not desirable can be avoided. Because we know the train accident occurred due to human error in its management. Then the government must work hard to improve existing community resources so that rail transportation remains a safer means of transportation.

One of the trains use the safety factor is the factor of road or railway. Railroads are an important factor supporting the safety of the traveling. In use the railroad must have a high resistance because it is used continuously and for a long time. Today many of the rails-to-rail long enough and yet there is change, even still railroads Dutch colonial relic that is still widely used.

Therefore, in this study tried to do some research to find out more about the quality and hardness of the railway.

The influence of surface roughness on the accuracy of the metal hardness test methods lndentasion of the test results is the method Brinnel hardness, vickers method, and rockwell method, in general, the object surface roughness affects the outcome of the metal hardness test . This effect will be very visible on hardness testing using methods Brinnel and methods vickers, the effect will be less on testing by the method of rockwell. A high degree of accuracy can be achieved by testing the hardness of metal on a certain degree of roughness in accordance with the test method.[1]

Testing is done is hardness, wear, and tensile test. From the test results showed that the optimum conditions obtained on the composition of 18% SiC and sintering temperature of 600^{o}C with the following characteristics: 88.96 HRB hardness, wear 2.575 x 10^{-5} g/mm^2.s, tensile strength of 19.77 kgf/mm^2. In terms of quality, with Al-SiC MMC 18% may be possible alternative materials as a substitute for iron drill on canvas the train brakes.[2]

The study of the mechanical properties of steel metal screw type plain P.25 and S.25 with Newton's method, the results of research tensile strength test was conducted by measuring the stress-strain using autograph while hardness tests were conducted by measuring Vickers Hardness Tester. Modulus of elasticity of steel S.25 was 54.80 Kg/mm^2 and 31.78 Kg/mm^2 for steel P.25. The average value of hardness is 227.2 kgf/mm^2 for steel S.25 and 195.6 kgf/mm^2 for steel P.25. These results indicate that the metal S.25 steel has a tensile strength and hardness is relatively better than steel metal P.25, according crimped measurements and calculations using Newton's method.[3]

Steel alloy is a mixture of carbon steel with other elements that will affect the properties of the steel, such as the nature of hardness, the clay, the speed of freezing, melting point, and so forth which aim to improve the quality and ability. The addition of other elements in carbon steel can be performed with one or more of the various elements, depending on the characteristics or specific properties in desired.

Alloy steel by alloys based on the elements that make it up can be divided into:[4]

1. Low alloy steel (the amount of alloying elements specifically < 8 %)
2. The high-alloy steel (the amount of alloying elements specifically > 8.0 %)

Alloy steel which covers about 15 % of all steel production, has a special utility because it is superior to carbon steel. In general, the steel alloy has the properties:

1. The high ductility without any reduction in tensile strength.
2. Hardenability when dipped in oil or air, and thus less chance of cracking or distortion.
3. Resistant to corrosion and wear, depending on the type of alloy.
4. Resistant to temperature changes, this means that his physical nature has not changed much.
5. Have the advantages and properties of metallurgy; such as grain and smooth.

The influence of alloying elements in steel, in addition to elements of ferro steel (Fe) and Carbon (C) is also contained additional elements other. Steel with a certain quality in accordance with the intended use is desired, and, can be obtained by the addition or subtraction of alloying elements to a certain percentage.

Physical Properties and Mechanical Materials

1. Physical Properties

On the physical nature will only discuss the physical properties of the microstructure. To hold the metal composition of the investigation with the help of a magnifying tool, for example loupe and a microscope specimens shall be flattened in advance with the scrub in the grinding machine, honed, polished, then sharpening approximately 60 seconds.[5]

2. Mechanical Properties

a. Deformation

Material deformation occurs when subjected to forces. During the energy-absorbing material is deform as a result of the forces acting along the deformation. Initial strain is directly proportional to the magnitude of the voltage, in addition to it, he is able to reversible. Once the voltage is deleted strain disappeared. Modulus of elasticity is the ratio between the stress and strain that is capable of turning.

At higher voltages occurs plastic strain, in addition to elastic strain. Plastic strain is not capable of turning on when the voltage is removed. This strain is called plastic strain. On the use of the products, we always avoid the plastic deformation so that the design calculations based on the diagram stress strain in the elastic region.[5]

b. Plasticity

Plasticity or the amount of plastic strain to fracture can be expressed in percentage cf extension AL/L_O. The next tenacity size corner sectional is Ao-At/Ao at the point of fracture. Clay materials typically have large cross-section shrinkage before fracturing.

<u>1) Hardness</u>

Is defined as resistance to deformation, and for these metals is a measure of its resistance to plastic deformation and permanent deformation. In general, hardness testing, consisting of: [6]

$$BHN = \frac{P}{\pi D/2 \left(D - \sqrt{D^2 - d^2}\right)} = \frac{P}{\pi D t} \ (kg/mm^2)$$

Where;

P = the applied load, kg

D = diameter of the ball, mm

d = diameter of the indentation, mm

t = depth of the impressions, mm

2) Vickers Hardness

In testing the Vickers Hardness (HV) is used penetrator made of diamond pyramid. Large diagonal former emphasis measured with a microscope. [6]

$$VHN = \frac{2P\sin(\theta/2)}{L^2} = \frac{1{,}854\ P}{L^2}\ \ (kg/mm^2)$$

Where;

P = load acting on a diamond penetrator (kg)

L = length of the diagonal average (mm)

θ = angle between the surface of the diamond opposite = 136^o

Testing with vickers hardness has the advantage can measure ingredients from small to large.

3) Rockwell hardness

Rockwell hardness (RC) is an index of other hardness used in engineering. As the indenter used: [6]

a) A hardened steel ball with a diameter of 1/16 inch listed in scale B.

b) Cone diamond with peak 120^o angle and rounding at the edges with a radius of 0.2 mm contained in scale cone.

The purpose of this study is expected to determine the extent to which the quality of the railway. So that can know the material content and subsequently drawn conclusions about its quality can be a reference for the development of a railway line better.

Research Method

1. Research Location

Location testing conducted Mechanical Engineering Laboratory Materials Engineering Laboratory Engineering UGM and UNS . While the test sample taken from Workshop PT Kereta Api Indonesia .

2. Preparation Materials and Equipment

a. Materials

The material to be tested in this study was the train tracks taken from the garage railway tracks Indonesia. Where on this occasion the author will try to find out the quality of the railway.

b. Specimen Preparation and Testing Tools

The first step taken was the initial cutting object. However, the initial cutting process is done for custody of excessive heat arising during the cutting, so expect no change of the mechanical properties and structure of materials . The results of this initial cuts will be made into a specimen - a specimen to be tested micro hardness

c. Surface smoothing

Before testing the test object before smoothed the surface first. To flatten the surface of the specimen first filed, then newly smoothed by rubbing the surface with sandpaper and which has a large number of hardness until smooth . In this study, using sandpaper with the numbers 100 , 180 , 400 , 600 , 1000.

d. Polishing

After the specimen is quite smooth, then the next step is to polish it with Autosol to get a smooth and shiny surface, so that the structure of the specimen into a seemingly clearly. Polishing performed before testing hardness and microstructure. On the polishing Autosol to the test object should use a soft cloth so that the surface of the object is really shiny and no scratches. Because if there is a scratch on the surface of the specimen, then the stroke will be markedly when viewed under a microscope.

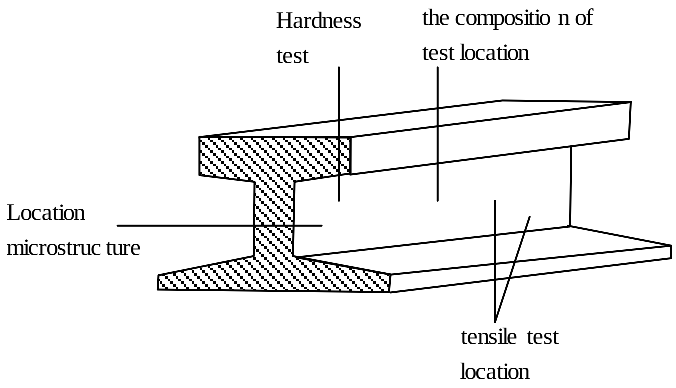


Figure 1. Position or parts testing

e. Etching

Etching is done only for the specimen to be viewed microstructure. Etching material receipts Nital 2% with a ± 60 seconds. Interest etching aims to reveal the microstructure under the microscope. Especially for steel materials should be made visible etching for micro structure.

3. <u>Flowchart of Research</u>

In carrying out the research the author has gone through several stages of research that can be translated into the following flow chart:

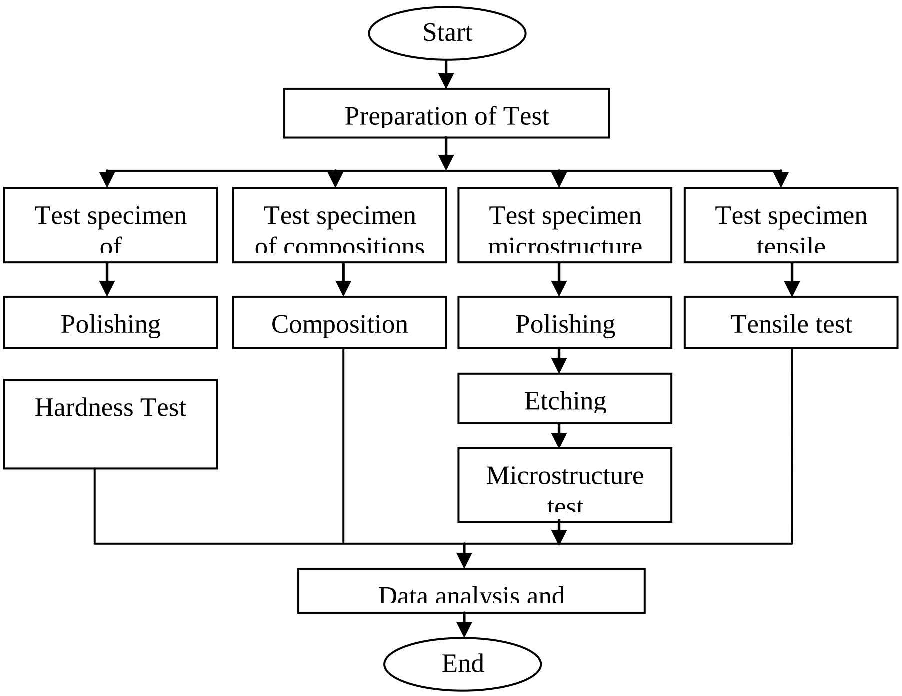


Figure 2. Flowchart of Research Methods

4. <u>Testing Methods</u>

a. Testing Micro Structure

This test aims to observe the microstructure and test specimens, especially in this test was the train tracks. After the test specimens were etched, next process is the process of observation of the specimen using Metallurgical Olympus microscope with a magnification of 100, and 200 times. After the observation object has the focus, the shooting process is carried out by using additional tools are Olympus Photomicrographic System using Fuji film Asa 200.

b. Hardness testing

Hardness of a metal is defined as resistance to penetration or plastic deformation. The purpose of testing is to determine the level of hardness of a material hardness, hardness testing method in this test is the Vickers testing method , using a diamond pyramid penetrator 136° with a load of 500 gf.

Procedures for implementing the Vickers hardness testing:

1) Selection of load used, is done by button-pushing load , this study used a load pressure of 500 gf.
2) Install and release the penetrator can be done by turning the screw pressing penetrator.
3) The test specimen is placed on the anvil , and the anvil is raised slowly by turning it clockwise until the test object touches the penetrator , short and long needle on the pointing device moves.
4) short needles are matched in number 3 in the red dot and a long needle should stop at 0 (*zero*) black scales.
5) Press the "Load" slowly, minute hand will mov .
6) After a long needle to move, wait until there bunvi "tick" approximately 10 seconds after pressing the "Load".
7) Anvil lowered by rotating the scroll wheel anticlockwise .
8) To obtain accurate data then taken five (5) points penetrator trampling on each specimen .

Diagonal produced is very small so that the measurement should be done with the aid of a microscope. The microscope used was Olympus Metallurgical Microscopes, with 100x magnification. From observations on a microscope in the can price (d) the amount of the strip, then this amount changed to millimeters (mm) where the enlargement l00x besarnva 1 mm = 38 strip. Once in the can price (d) in millimeters , then only the Vickers Hardness (VH) can be determined by the above equation . It is a concern in the preparation of materials for hardness testing is the alignment and flatness between the top surface and the bottom surface of the specimen, so that acquired former stamping horizontal penetrator. This will determine the accurate amount of diagonal former stamping formed penetrator for test equipment Vickers penetrator.

In Vickers hardness testing , former stamping penetrator that must be measured to find the price of hardness by the formula:

$$\text{Vickers Hardness} = \frac{2P\sin\frac{\theta}{2}}{d^2} = 1{,}854\frac{P}{d^2}\ \ (\text{kg/mm}^2)$$

where , P = load pressing (kg)

d = diagonal oppressor penetrator (mm)

θ = < 136° for diamond pyramid

To calculate the diagonal oppressor penetrator must use the microscope with the following provisions:

For scale up l00 × every 38 strip = 1 mm

This provision is a standardization of time microscope that researchers use laboratory testing material that belongs to the Mechanical Engineering Department of UGM. Because of the results of the penetrator oppressor No 2 diagonal, diagonal d_1 and d_2, the value d taken the average of the second diagonal , because sometimes d , and d_2 can be different. As for calculating the area of a former stamping penetrator using the equation:

$$A = \frac{d^2}{1{,}854} \ \text{mm}^2 \qquad \text{where, } d = \frac{d_1 + d_2}{2}$$

c. Composition testing

Tests conducted to determine the composition of the carbon content of steel contained in the railway.

d. Tensile Tests

Tensile test done to complete the engineering design information. Basic strength of an ingredient and as supporting data that has been standardized by the load tensile one axis which grew by continue and held together with the observations on the extension and reduction experienced cross-section of the test specimen.

The parameters are searched and testing include: Tensile Strength; The yield strength and the yield point; Percentage of renewal; Reduction sectional; Modulus of elasticity. This research uses a universal tensile testing machine and dial indicator. The first step of measuring the dimensions of each object to be tested. The dimension measured is the length of the test specimen and wide profile. Then put the specimen in a tensile testing machine to use the tools. Install and set the dial indicator on the position of the needle indicates zero as an initial reference, Enter extensive data profiles machined specimen on the computer test . Then turn the machine as a step of the tests. And the results of this test (maximum load and the load can be suppressed and the fracture will be seen from the results of this machine printer) .

The amount of tension of each specimen can be calculated by the equation :

Stress equation is:

$$\sigma = \frac{F}{Ao}$$

while the strain equation is:

Where : σ = tensile stress (N/mm^2)

F = maximum load (N)

Ao = cross-sectional area at first (mm^2)

ε = strain (%)

ΔL = the length (mm)

Lo = length of origination (mm)

Lt = length after fracture (mm)

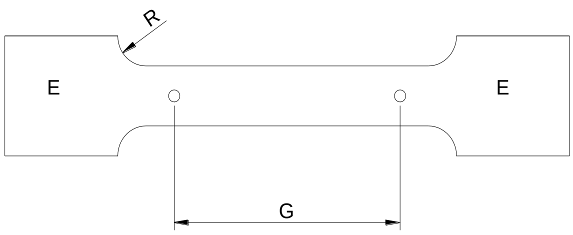


Figure 3. Sample tensile test

Information:

E = End of test objects , to handle with or without holes .

G = Signs gauge length to measure accurately the length changes before, during , and after the test
R = Fillet to reduce stress concentrations

The size of the test specimen
Making the tensile test specimens in this study based on ASTM standard E-23, 1992.

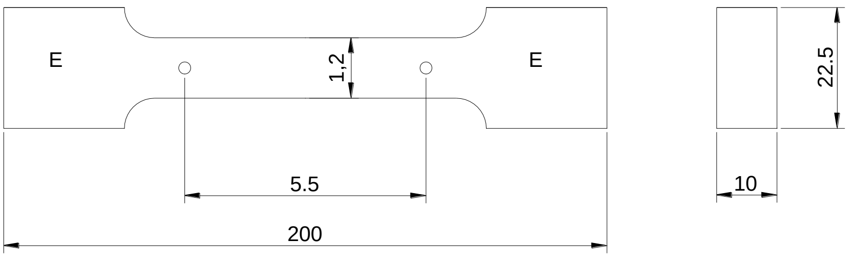



Figure 4. Tensile Universal Testing Machine

Results and Discussion

1. Research Results
a. Composition testing

Composition Testing conducted at the Laboratory of Mechanical Engineering UGM. And testing the composition of the data to be obtained as follows.

Table 1. Data from the composition of Test Objects Railways

Elemen	Persentage (%)
C	0.5890
Si	0.1846
S	0.0188
P	0.0210
Mn	1.1535
Ni	0.0148
Cr	0.0351
Mo	0.0027
Cu	0.0629

w	0.0068
Ti	0.0250
Sn	0.0044
Al	0.0082
Pb	0.0026
Ca	0.0000
Zn	0.0027
Fe	97.89

Source: Lab. Mechanical Engineering UGM

b. Photo microstructure Observations

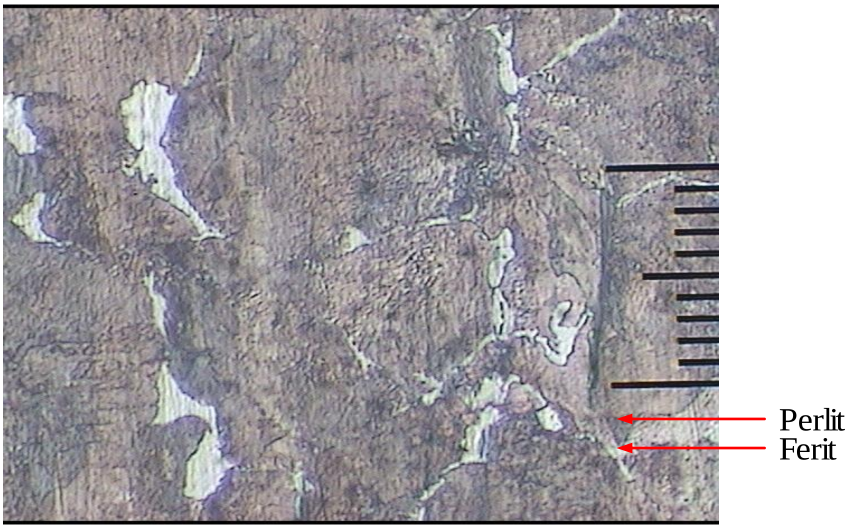


Photo railways 50 micron scale up 200X

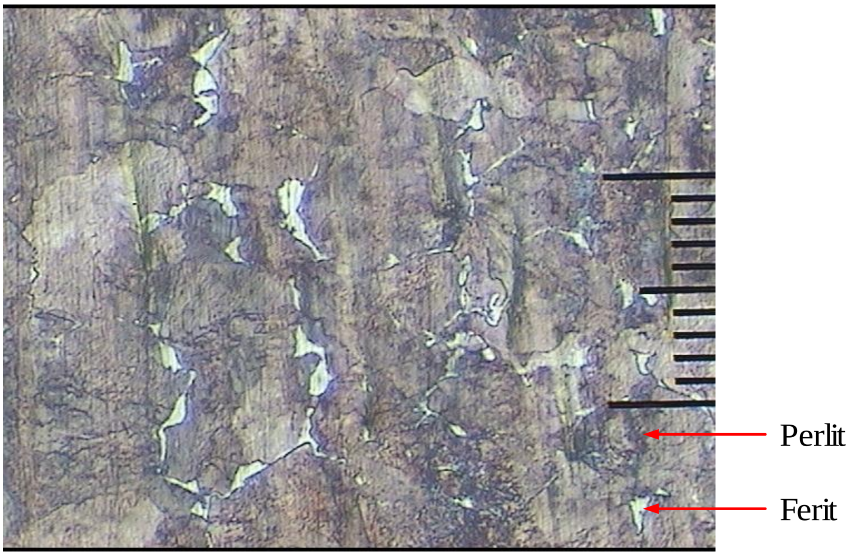


Photo railways 100 micron scale up 100X

Figure 5. Photo Microstructure Test Results

c. Hardness Testing Results

This research was conducted in the laboratory of Mechanical Engineering UNS with the aid of micro vickers hardness test, the results of these research are as follows:

Table 2. Values tensile on railway

Point	D_1 µm	D_2 µm	$D_{average}$ µm	Price Hardness (HVN) Kg/mm²
1	37,16	36,17	36,6	276,0
2	35,17	35,52	35,3	296,7
3	37,45	38,09	37,7	259,9
4	33,17	35,94	34,5	294,2
				Rata-rata= 281,7

Ket : - Load (P) : 200 gf
- Penetrator : Pyramid diamond

d. Tensile Testing Results

Execution of the tests carried out in the Laboratory of Mechanical Engineering University Diploma March Surakarta . And a tensile test conducted obtained data generated maximum tensile stress and the test object .

Table 3. Prices On Tensile Strength Test Objects Railways

Materials	Maximum load (N)	Initial cross-sectional area (mm²)	Maximum strain (%)	Maximum tensile strength (N/mm²)
I	16,27	120	28,0	0,135
II	16,26	120	21,0	0,135
III	16,16	120	21,0	0,134

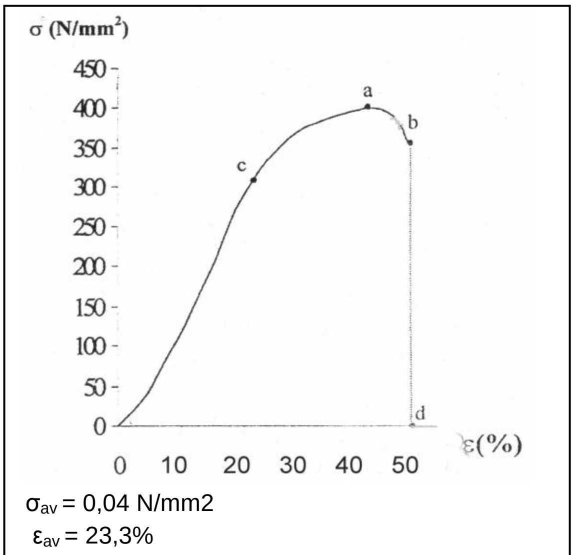
$\sigma_{average} = 0{,}134$ N/mm^2

$\varepsilon_{average} = 23{,}3$ %

Modulus elastisity:

$$E = \frac{\sigma_{av}}{\varepsilon_{av}} = \frac{0{,}134 \ \text{N/mm}^2}{23{,}3\%}$$

E = 0,005 Mpa



Source: Lab. Mechanical Engineering UNS

Fig 6. Graph Tensile Test Result

Information:

a = maximum tensile stress = 400 N/mm^2.
b = tensile stress at the time of fracture = 354 N/mm^2.
c = yield strength = 305 N/mm^2.
d = maximum strain = 46%.

From the results of photo railroad microstructure after correlated with the photographs in the book Metallography Metallography ASM Handbook Committee and Microstructur, analysis obtained as follows :

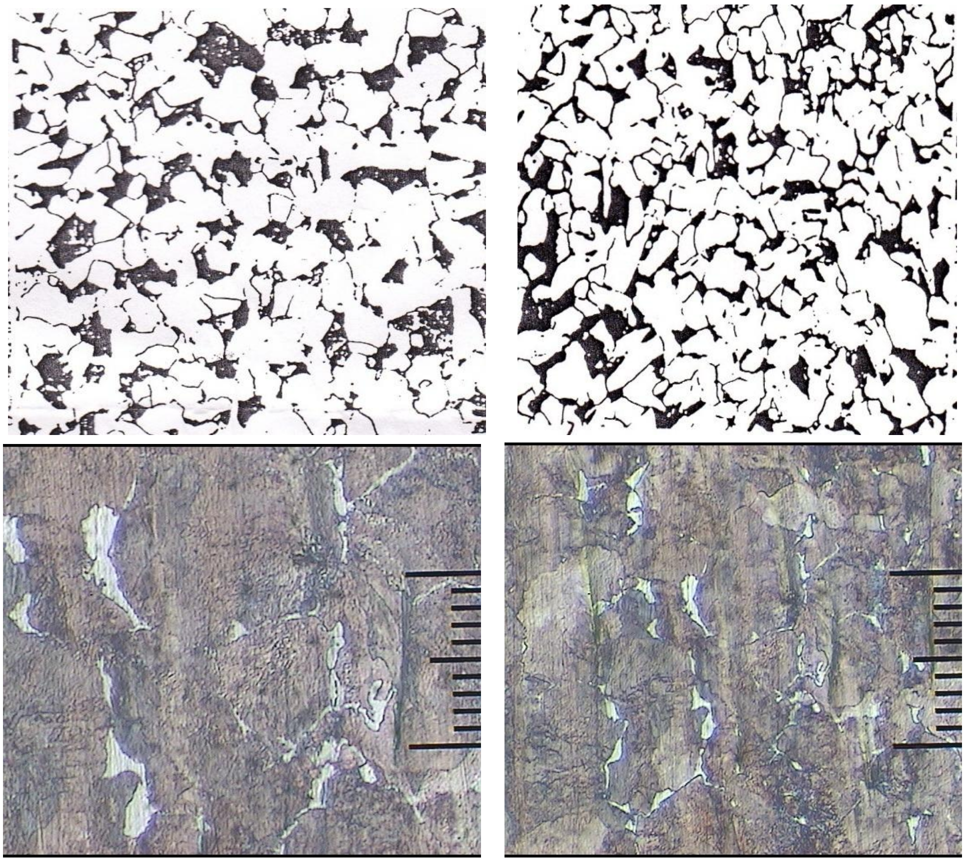


Figure 7. Comparison of results for the Metallography Books and Results Eksperiement microstructure

The images of the microstructure appears that there is the content of ferrite and pearlite. Pearlite structure is more dominant than the ferrite. It shows that the level of hardness of the railroad tracks are not too big or not too high carbon content. In other words, the carbon content is directly proportional to levels of hardness while the ductility is inversely proportional to the price of hardness. If it has a high tenacity, the strength of the greater tarikpun.

From the test results obtained hardness violent price average of the railroad is 281.7 HVN. Average price impact of the railroads alone amounted to 13 joules, the impact of price tenacity price obtained an average of 0.162 joules/mm^2. Meanwhile, the average tensile strength and railways of 0.134 N/mm^2.

As it is known that the railroad received a considerable burden, besides the railroad also always rub or collide with the wheels of the train, then it should be required railroads to support the weight of despair and have hardness adequate and resistance Wear sufficient high. In other words, it takes considerable force balanced with high ductility, it relates to the price gets high enough tensile strength. It shows the nature of the railway line itself that has a fairly high elastic deformation. We can see the mounting rail spaced on each section mounting rails. It aims to make room on the railroad strained during the day or when exposed to hot sun and return to its original shape when not exposed to the hot sun.

Conclusion

After testing on the railroad which includes hardness testing, impact testing, tensile testing, and testing of microstructure obtained the results as follows:

1. On the railways when viewed from microstructure appears the structure of pearlite and ferrite. The structure is more dominant than the ferrite pearlite. An element of perlite ranges between 60% and 40% is a ferrite element. From this vantage point we can infer the carbon content of the railroad that is equal to 0.32% carbon, or it could be classed railroads including carbon steel into being.
2. From the arrangement of the microstructure of the above if it is associated with a higher rate of hardness, the hardness railroads are not too big that the price of the average hardness of the railroad tracks at 281.7 HVN.
3. From the figures above test results it can be concluded that although the carbon content railroads including carbon steel was however railroads have high ductility and toughness. That's what makes the train tracks can support the weight and pressure of a huge train.

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