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Comparison between SKS 3 and SCM 440 Steel Materials for the Location PIN of Welding JIG

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Abstract

Welding in manufacturing industry plays an important role. In welding, the location pin process is one of the important part that determines the precision of the resulting product. The most common material for the location pin is SKS 3 steel. This research will compare it with another material, SCM 440 steel, which is cheaper than SKS 3. The cost of SCM 440 is 23 % cheaper than SKS 3. The results of the mechanical test and metallurgical prove that the SCM 440 material is stronger and tougher than the SKS 3. Therefore, It can be ascertained that SCM 440 can replace SKS 3 as the material for the material of the location pin.

Keywords: The location pin, SKS 3, SCM 440, mechanical test and metallurgical test.

INTRODUCTION

One of the leading companies in Indonesia is the motorcycle manufacturer. In these kind of companies, they usually have welding shop. The shop in the production process is an important part. For example more motorcycle manufacturer, the shop produces various types of body frame of motorcycle. Welding of the frame comp is aided with an attachment like a jig. The usefulness of the jig is to stabilize welding process to meet with the desired dimensions and speed up or to simplify the setting process. Therefore, it is very important to maintain the quality of the jig.

The location pin is (figure 1) one of the important part for welding jig. The most common material for location pin is SKS 3 steel. This type of material is high carbon steel that has quenching and tempering before process. The heat treatment process is to achieve maximum toughness and ductility at a specified hardness and strength.

The heat treatment is strongly influenced by the treatment parameters and the meticulous control of these parameters. It is necessary to obtained a martensitic structure without forming ferrite and retained austenite [4]. Furthermore, the carbides precipitated in the quenched and quenched-and-tempered microstructures also exert effects on the material properties hardness, wear and corrosion resistance [3].

The cost of producing pin of SKS 3 is more expensive than SCM 440 (source: SCK Metal Heat Treatment Prima, 2017). In the factory plant, it needs a lot of pin replacement. The substitution material (SCM 440 steel) should has mechanical properties almost similar with material properties of the SKS 3, without reducing the toughness and strength.

Welding Jig and Pin

Welding jig is a jig assembly that serves to grip objects when the welding is in process. The use of welding jig is required to make easier and also accelerate the welding process. In addition, the use of welding jigs is also to determine welding accuracy. The pin as a part of the welding jig is used to make position of the workpiece towards a more detailed dimension. Figure 1 show a picture of welding jig and its components.

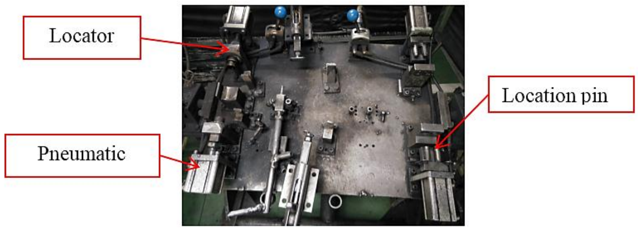

Figure 1: Welding jig

SKS 3 and SCM 440

Based on JIS G 4404-2006, SKS 3 steel material (equivalent with AISI 01 & 100MnCrW4) is high alloy steel with the chemical composition can be seen in table 1. Otherwise, SCM 440 material (equivalent with AISI 4140 & 42CrMo4) is an intermediate alloy steel with the following composition specifications (JIS G 4053-2008) as in table 1.

Table 1. Chemical Composition of SKS 3 and SCM 440

		SKS 3	SCM 440
Chemical Composition(%)	C	0.9-1.0	0.38-0.43
	Si	0.35	0.15-0.35
	Mn	0.9-1.2	0.60-0.90
	P	0.03	0.03
	S	0.03	0.03
	Cr	0.5-1.0	0.90-1.20
	Cu	≤0.25	-
	Ti	0.1-0.2	-
	W	0.5-1.0	-
	Ni		0.25

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RESEARCH METHODS

a. Working Principle and Calculation of Pin Forces

The pin is driven by a specific pneumatic force (F) held by the pneumatic system. If the welding jig is used for mass production, then the pin movement is going to be repeated until it can be assumed will get fatique. In addition, the force received by the pin is the compression force (F) that is influenced by the force given by the pneumatic system.

In general the working principle of the pin can be seen in figure. 2. The pin movement will be controlled by pneumatics system which will produce force (F) and move into the hole of bushing to make position of the workpiece. When the pin goes into the bushing, it will produce a shear force (Fs) from the bushing. The force is similar as the shear force given by the strength of the bolt tightening in the pneumatic position (Fy). The working principle of the pins can be represented in the following figure 2 and simplified in the free body diagrams in figure 3.

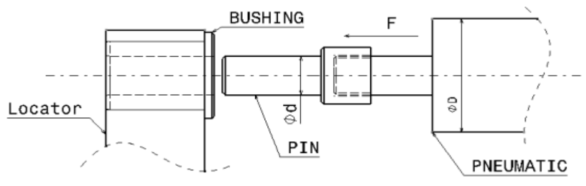
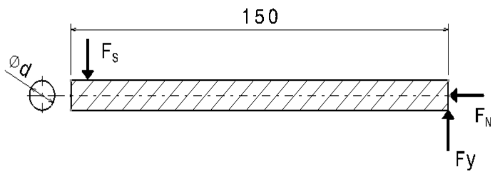


Figure 2:The location pin



$F_s = F_y$(tightening bolt of locator)

Figure 3: Free body diagram of the location pin

Normal Force calculations

$F = A_1 \times P \times \beta$ ……………...... (1)

$\boldsymbol{\sigma} = \frac{F}{A_2}$ (MPa) ……………… (2)

F : Output pneumatic force (N)

A_1 : Out stroke piston in pressurized area (mm²), D=80 mm

A_2 : Surface area of the pin (mm²), d=40 mm

P : Set pressure (MPa), *Theoretical output table at out stroke (35.19 MPa)* [9])

β : Load rate (25% [9])

The output force is calculated as,

$F = A_1 \times P \times \beta$

$= \frac{\pi}{4}(80\ mm)^2$ x 35.19 MPa x 25%

= 44.2 N

The normal stress on pin is calculated as,

$\boldsymbol{\sigma} = \frac{F}{A_2}$

$= \frac{44.2\ N}{\frac{\pi}{4}(40mm)^2}$

= 35.2 MPa

Shear Stress Calculation

The shear force (Fs) in this case is assumed for tightening bolt at the locator, and it can be stated that the shear stress (τ) is very small, because of the roughness between pin and bushing is very smooth as about Ry 6.3. Then, the normal stress of 35.2 MPa and the shear stress are still acceptable. It can be seen from figure 4, which is the acceptable mean stress is 176 MPa.

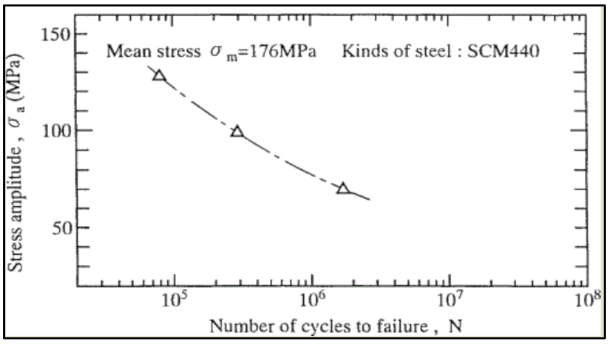


Figure 4 : SN curve of SCM 440 steel[8]

Chart of Research

There are two types of tests that will be applied in this research that is static and dynamic test. The static test to be applied is tensile test. The tensile test will feature a stronger material with a higher tensile strength value. Dynamic testing to be applied is impact testing. The impact method to be used is a Charpy test. It will display a better toughness value by being represented by the energy toughness of each material.

In addition, to support or validate the both above tests, the metallographic test is performed. The test produce the phase form that can be formed from both materials. Thus, it can be known also the character of the produced material.

Mechanical test, on both types of materials, firstly applied hardening process of 820ºC with tempering 60 minutes for SKS 3 material [5] and the same treatment for SCM 440 material [6].

Finally, to validate the accuracy of the mechanical test, The microstructure test is done to determine the phase structure formed for each material. The problem analyzed is comparing the stress received by two types of material as the flow chart in figure 5.

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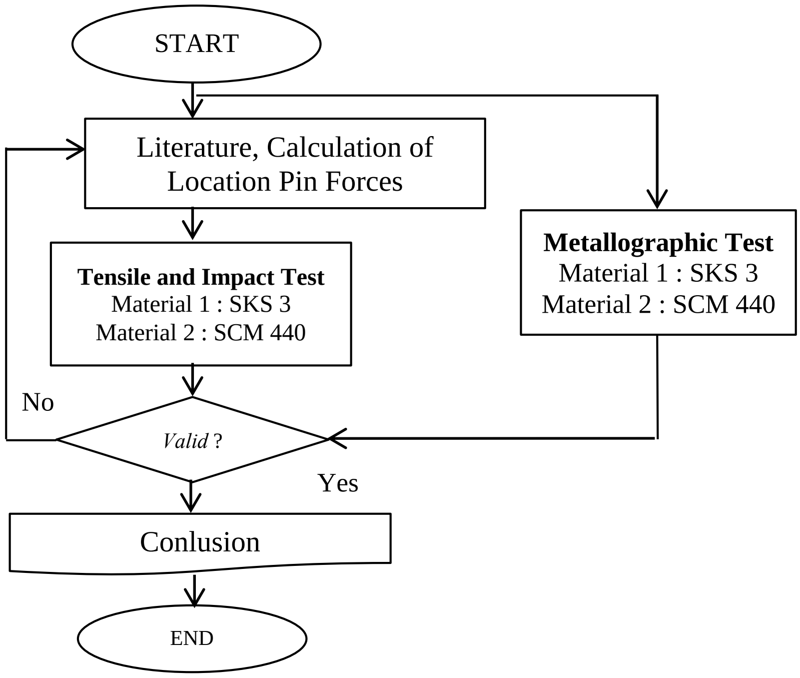


Figure 5: Flow diagram of research

RESULTS AND DISCUSSION

a. Tensile Test

Tensile test is performed to know the magnitude of tensile strength of materials. Dimensions of tensile test specimen is according to the ASTM E8/E8M as can be seen in figure 6.

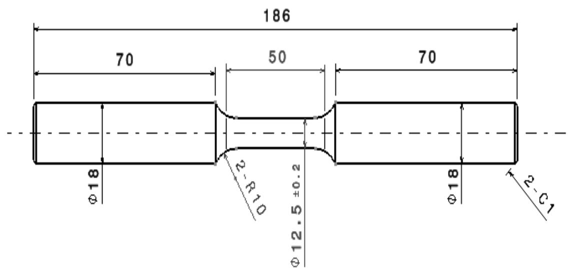
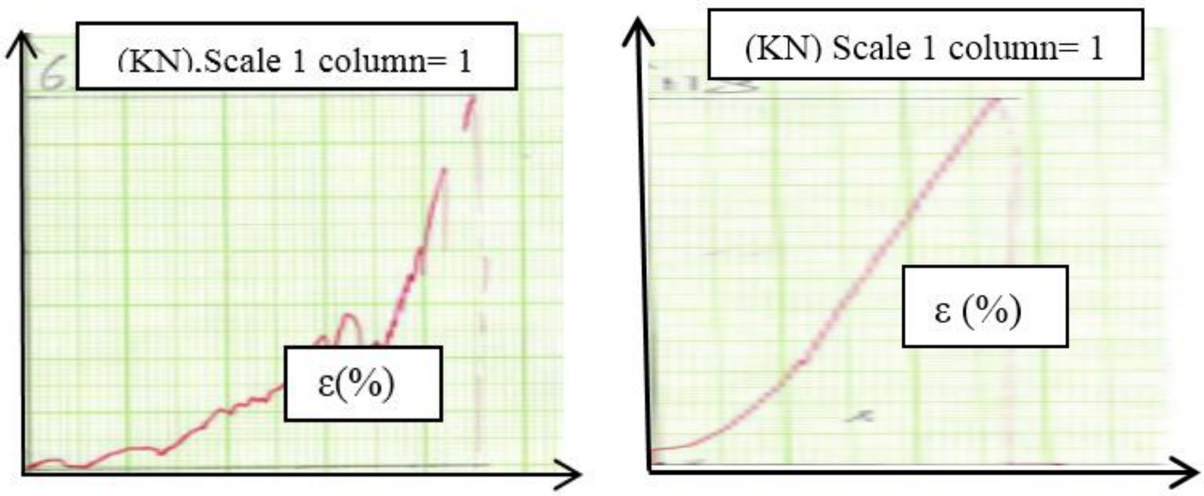


Figure 6: Dimension of tensile test specimen



(a) **(b)**

Figure 7 : Load vs strain of SKS 3 (specimen 1(a)) and SCM 440 (specimen 3(b))

The tensile test graph in figure 7, based on the specimen 1(SKS 3) and specimen 3 (SCM 440). The detail of the ultimate strength can be seen in the table 2. The ultimate strength of SCM 440 is 1776 N/mm^2, which is stronger than SKS 3. The reason is because SCM 440 contains less carbon.

Table 2. Tensile Test

Specimen No.	Ø (mm)	A_o (mm^2)	F_m (KN)	σ_u (N/mm^2)	ε	Remarks
1	9.18	66.2	69.0	**1043**	8.6	SKS 3
2	9.09	64.9	62.0	956	8.9	SKS 3
3	9.20	66.4	118	**1776**	5.7	SCM 440
4	9.05	64.3	130	2022	5.7	SCM 440

Ø:diameter gauge length, A_o:area, F:force$_{max}$, σ_u:ultimate strength, ε:elongation

b. Impact Test

In the charpy impact test, the energy absorbed to break the specimen is performed to determine how much energy can be absorbed by the material. Material impact energy can be calculated using the equation :

$$I = EI/A \quad \text{……………………..} \quad (3)$$

I = Impact toughness (J/cm^2)

EI = Energy impact (J)

A = Area (mm^2)

The dimensions of impact test specimen according to ASTM 23 can be seen in figure 8.

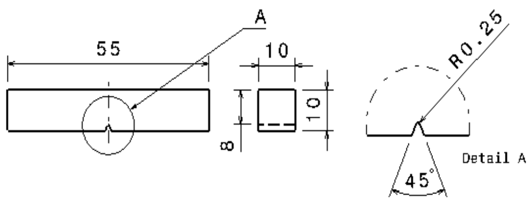


Figure 8: Dimension of impact test specimen

Figure 9 shows that SCM 440 material can receives greater energy than SKS 3, about average 35.8 J/cm^2.

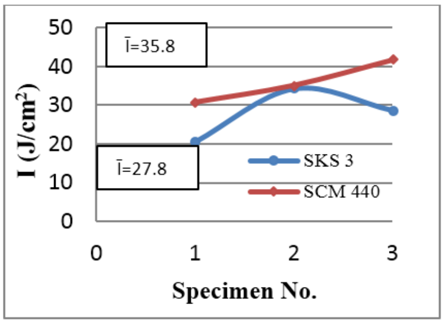


Figure 9: Graph of impact test

c. Observation of Microstructure

The metallographic test, used an optical microscope of 100 x magnification as in figure 10 and 11.

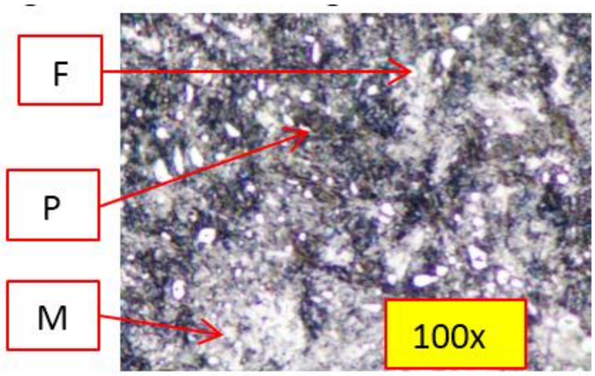


Figure 10: Microstructure of SKS 3

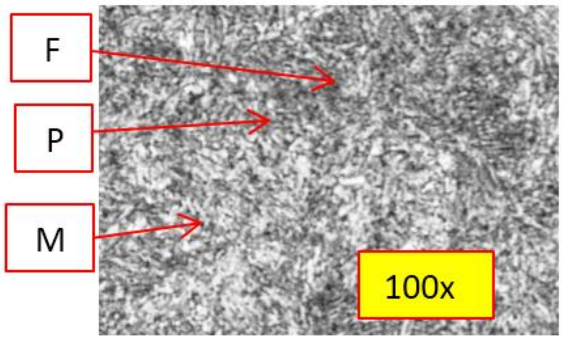


Figure 11: Microstructure of SCM 440

P = Pearlite

F = Ferrite

M= Martensite

The purpose of microstructure test is to know the structure of materials contained in the research specimens as micro photographs. Each specimen has different structures depending on the properties contained by the material.

Specimen in figure 10 and 11 is the microphotographs of specimen after quenching and tempering process (hardening) with a heating temperature of 820ºC using water as cooling medium. The ferrite structure is the lightest, while the darkest is pearlite and gray-blackish shape resembles a needle is a martensite structure. It can be seen in figure 11, the pearlite structure is more than that in figure 10. Then, in figure 10, ferrite is more easily to see than that in figure 11. In that case, the brittleness is shown in figure 11 with a large and uneven number of martensitic structures.

When the holding time on the transformation is short, or relatively rapid cooling, it is not enough time for the carbon atoms to diffuse more extensively. The result of transformation is fine pearlite. When the cooling rate is slow, carbon has enough time to diffuse longer and travel longer distances to form a coarse pearlite. But, in this case, the two materials are applied to the same cooling rate, The difference is the less carbon content of SCM 440 (table 1) will cause less atomic motion which resulting in a fine pearlite. Similarly, martensite is formed on SCM 440 materials, due to rapid cooling and less carbon content (table 1). Then, the carbon does not have enough time for diffusion more extensively.

In addition to the two images, the structure of figure 11 is rougher and less homogeneous structure in figure 10, which is relatively uniform and smoother. Materials with fine grains have better ability to withstand the dislocation movement than the coarse grain (large), because fine grains have a larger total grain boundary area [7].

CONCLUSIONS

The result of tensile test is the SCM 440 material received a ultimate strength value of approximately 1776 N/mm^2 (see table 2 for specimen 3). It is better than SKS 3 result. In relation to that, from the impact test it is also similar that the SCM 440 material can absorb more energy than the SKS 3 material.

Microstructure test can validates the above statements, that the microstructure of SCM 440 steel shows more pearlite structures and produce less ferrite, whereas SCM 440 steel will be stronger than SKS 3.

In conclusion, it is shown that SCM 440 steel can replace SKS 3 steel, because SCM 440 is stronger and tougher than SKS 3.

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