

## Comparison Of The Harmonic Content Effect On Induced Current Between 3%SiFe (Crgo) And Cold Rolled Non Grain Oriented (Crngo) Core Material

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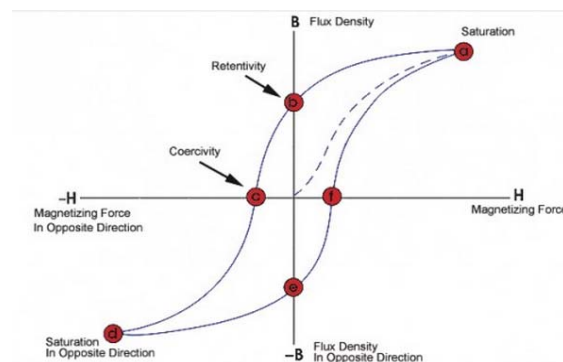
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**Abstract:** This paper is about to investigate the harmonic content effect on induced current between Cold Rolled Non Grain Oriented (CRNGO) and 3% Si Fe (CRGO) core material. The experiment method that used is Single sheet tester (SST) in order to measure the harmonic content. The input voltage adjusted at 0.2T, 0.5T and 1.0T. From the result of this investigation find that the 3<sup>rd</sup> order harmonic factor of CRNGO is lower than 3% SiFe (CRGO) about 83.10% at 0.5T. The 5<sup>th</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) about 20.18% at 0.5T. It means that harmonic is affected by ingredient in core material.

**Key words:** Harmonic, Harmonic Factor 3% SiFe, Single Sheet Tester (SST)

### INTRODUCTION

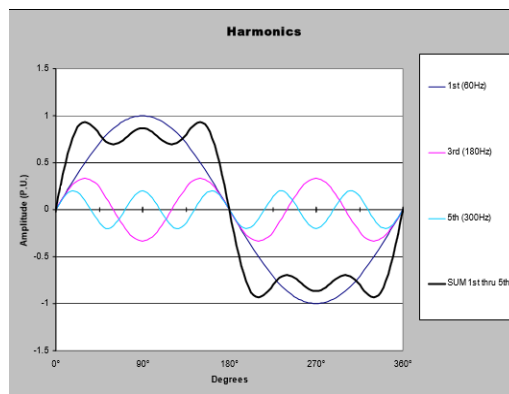
Early 1885, the first transformer core was made by carbon steel followed by silicon steel. Nowadays, it has been changed to Cold Rolled Grain Oriented (CRGO) laminations (Themistoklis, D., *et al.*, 2010). Other than that, Amorphous steel also used as transformer core. They have been selected because of their several characteristic that can give an advantage to the performance of transformer itself. However, there is a problem need to be considered in order to make sure the core material will give a better performance to transformer. The problems is harmonic occurred in those two core material (Syafudin Masri, *et al.*, 2011). Harmonic will disturb voltage and current output at transformer and will bring to some losses to the power system Syafudin Masri, *et al.*, 2011). Many researchers have trying to find what cause of harmonic (Themistoklis, D., *et al.*, 2010). Harmonic will give an effect to distribution transformer no-load loss (Themistoklis, D., *et al.*, 2010). Cold Rolled Grain Oriented (CRGO) is widely used as core material in transformer design and stator or rotor part in electrical motor. It is chosen because of the magnetic characteristic that satisfies the requirement of electrical demand. It contains silicon level of 3% Si Fe (en.wikipedia.org/wiki/Electrical). Cold-Rolled Grain Oriented (CRGO) is usually supplied by producing mills in coil form and it has to be cut into "lamination" which are then will be used as transformer core (Nada Kosutic hulita, 2011). Grain Oriented steels is also decarbonised and has not more than 0.06% of carbon in their chemical composition, which will prevents ageing of the steel (Saif Qureishi 2004). As refer to Fig. 1, the core is magnetized by magnetic field (H) is called magnetizing force. The magnetic flux density (B) of the core will increase and saturates at the knee point and then it will starts decreasing as magnetizing force (H) decreases. At point b, called Magnetic Retentivity where it means no magnetic field force is applied to the material but still magnetic flux density is not zero in the material. At point C, called Coercive Force where by applying magnetic field in opposite direction will make the magnetic flux (B) is zero. The same phenomenon will happen if the flux applied in the opposite direction in another cycle. These called hysteresis loop. Lower Magnetic Retentivity in magnetic material is the loss of magnetic field applied to make magnetic flux zero. So, CRGO has a small hysteresis loss compared to other material (<http://kiran111.hubpages.com>).



**Fig. 1:** B-H curve for CRGO (<http://kiran111.hubpages.com>).

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The same phenomenon will happen if the flux applied in the opposite direction in another cycle. These called hysteresis loop. Lower Magnetic Retentivity in magnetic material is the loss of magnetic field applied to make magnetic flux zero. So, CRGO has a small hysteresis loss compared to other material (<http://kiran111.hubpages.com>). CRNGO contain between 0.5 and 3.25% Si plus up to 0.5% Al, added just to increase resistivity and lower the temperature of primary recrystallization (<http://eng.rusteel.ru/biznes-napravleniya>). It has a random orientation. CRNGO is less expensive than CRGO. It is only used when cost is more important than efficiency. It also used for applications where the direction of magnetic flux is not constant as in electrical motor and generator with moving parts. Harmonic in simple word means a wave whose frequency is an integer multiple of the fundamental frequency (Dr. Mohamed Fuad Faisal, 2012). When the higher frequency value added to fundamental frequency waveform, it will become distortion to the fundamental (Dr. Mohamed Fuad Faisal, 2012). As refer to Fig. 1, fundamental frequency is 60Hz, when the frequency is added by multiple of three, the order of harmonic will become third order. Same if frequency added by multiple of five, the order of harmonic will become fifth order. It clearly stated that sum of first harmonic until fifth harmonic will become a complex waveform. Positive sequence of harmonic will have same phase rotation as fundamental voltage frequency, 50 Hz. First, seventh, thirteenth, nineteenth order of harmonic are the example of positive sequence harmonics (Dr. Mohamed Fuad Faisal, 2012).



**Fig. 3:** Harmonic definition (Michael Leporace)

Graphical method is used to calculate harmonic content from the graph. The equation for harmonic content shows by the Fourier Series such as:

$$Y = F_0 + F_1 \sin(\omega t + \phi_1) + F_2 \sin(\omega t + \phi_2) + \dots + F_n \sin(\omega t + \phi_n) \tag{1}$$

The objective of this investigation is to compare the harmonic content in 3% Si Fe and Amorphous ribbon core material.

**Experimental Setup:**

The methodology that used to investigate this material is shown in the flow chart in Fig. 6. The method used to measure the harmonic content by using the Single Sheet Tester which is SST having closed magnetic path (a closed type of SST) has a problem that measurement accuracy of magnetostriction is considerably affected by electromagnetic force between specimen and yoke. Flux closure yoke are used can be single sided or double sided. If single sided yoke, eddy current pools can form in the strip where flux leaves or enters its normal to its surface. Fig. 5 shows the single sheet tester with single yoke. With double sided yokes these eddy current effects largely cancel. The equation used to get input voltage and this voltage need to supply at windings coil with Tesla of flux density.

$$V = 4.44 \times B \times N \times f \times A \tag{2}$$

- where
- V = Voltage
- 4.44 = Constant
- B = Tesla
- N = Number of winding turn = 125 turns
- f = Frequency = 50 Hz

The experiment setup is shown in Fig. 4 .Oscilloscope is important in order to get the waveform for harmonic current. Then, we should know all this value below:

A = Cross sectional on the surface of yoke =  $n \times t \times w$  [m]  
 N = number of layer of yoke lamination = 40 layers  
 t = thickness of yoke lamination [m] = 0.3 mm for M5 grade material  
 w = width of yoke lamination [m] = 3cm

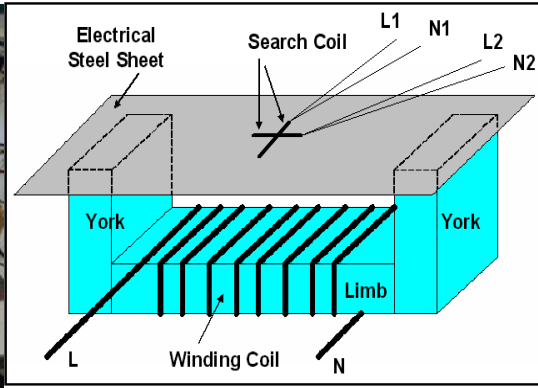
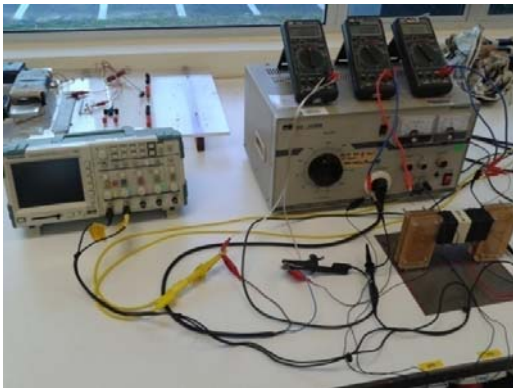


Fig. 4: Setting of experiment for SST

Fig. 5: The single sheet tester with single yoke

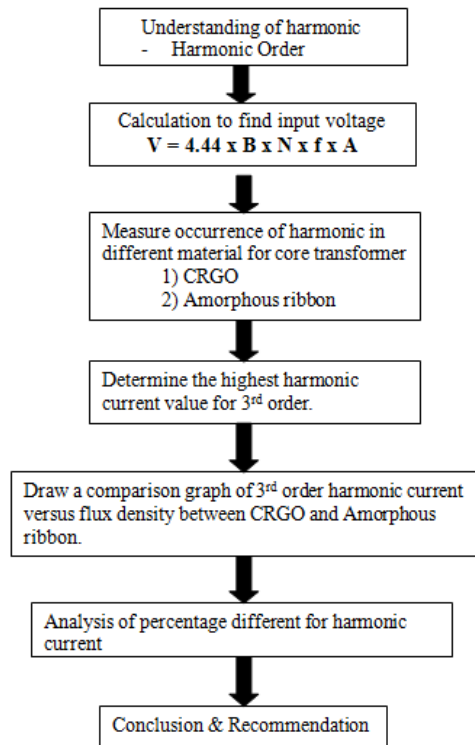


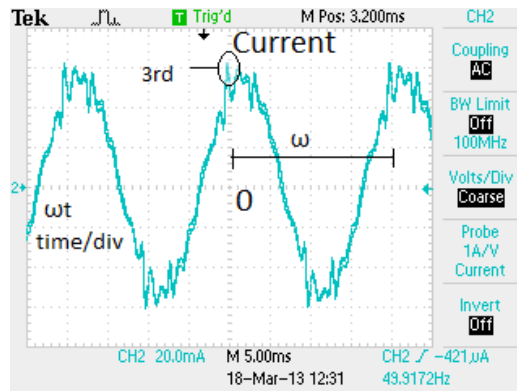
Fig. 6: Flow chart for methodology

## RESULT AND DISCUSSION

Input voltage is getting by calculating using Eq. 1. Three condition need to be considered are under excited, operation and saturation.

Table 1: Calculation result for input voltage

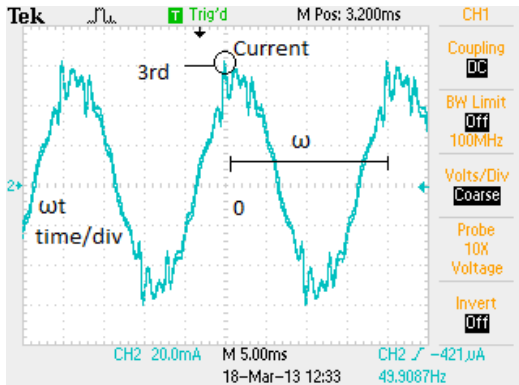
Condition	Flux (T)	Input Voltage (V)
Excited	0.2	2.0
Operation	0.5	5.0
Saturation	1.0	10.0



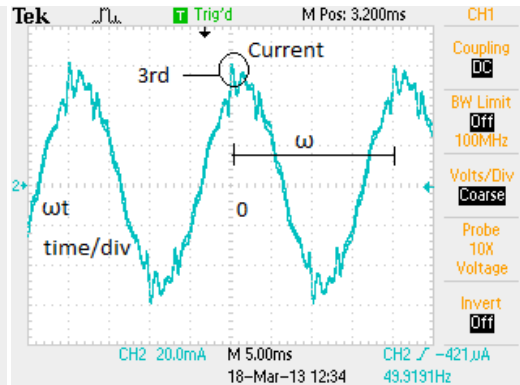
**Fig. 7:** Induced current for flux density of 0.2T, 50Hz

For under excited mode, 3% SiFe core material shows 0.2T given for input voltage can refer to Fig. 7, which

is the highest induced current value of 0.064A. While, in operation mode, 0.5T given for input voltage can refer to Fig. 8, which is the highest induced current value is also 0.064A and for saturation mode, 1.0T is given for input voltage can refer to Fig. 9, which is the highest current value is 0.060A. Fig. 7, Fig. 8. and Fig.9 shows the x-axis is referred to time/div which in these case the time is 20 ms.

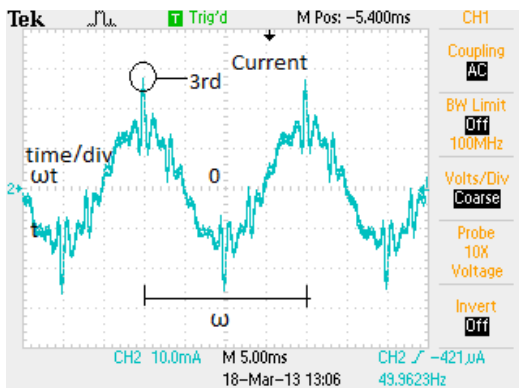


**Fig. 8:** Induced current for flux density of 0.5T, 50Hz

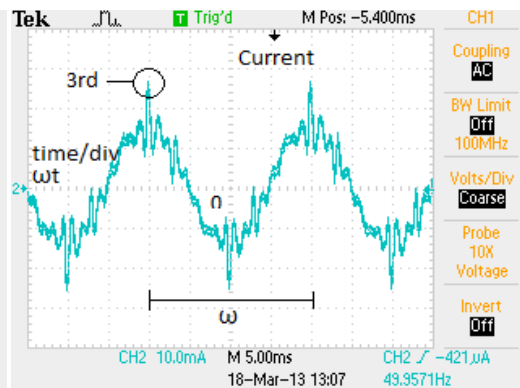


**Fig. 9:** Induced current for flux density of 1T, 50Hz

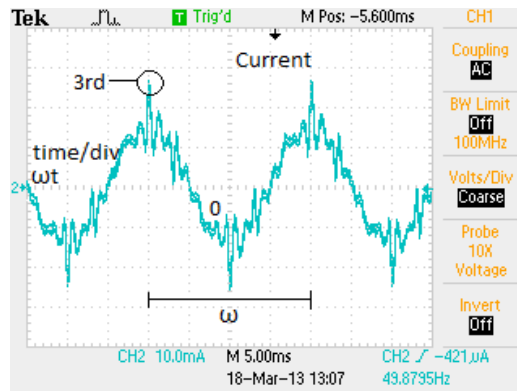
Continue with under excited mode, for CRNGO at 0.2T given for input voltage in Fig. 10 shows that the highest induced current is 0.028A. Next, for operation mode at 0.5T, given for input voltage in Fig. 11 shows that the highest induced current is 0.027A. For saturation mode at 1.0T given for input voltage in Fig. 12 shows that the highest induced current is 0.028A. Fig. 10, Fig. 11 and Fig.12, x-axis is referred to time/div which in these case the time is 20 ms.



**Fig. 10:** Induced current for flux density of 0.2T, 50Hz



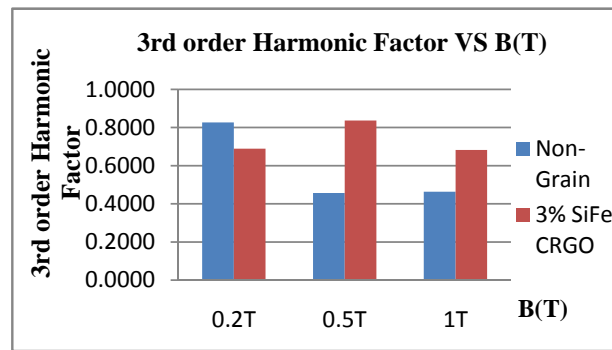
**Fig. 11:** Induced current for flux density of 0.5T, 50Hz



**Fig. 12:** Induced current for flux density of 1T, 50Hz

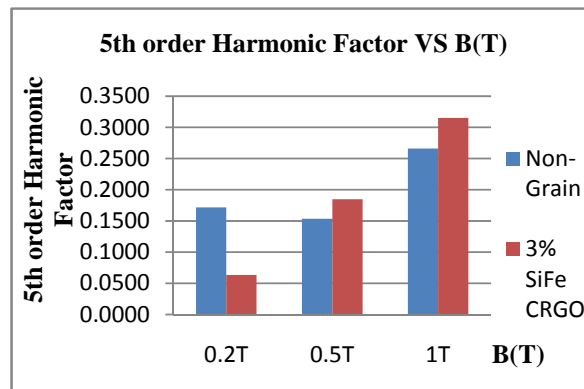
The method that used to find the harmonic factor (HF) and Total Harmonic Distortion (THD) are using graphical method found from the Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. 11, and Fig. 12. From Fig. 13 shows a 3<sup>rd</sup> order harmonic factor of CRNGO material is higher than 3% SiFe (CRGO) at 0.2T is 16.63%. The 3<sup>rd</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) at 0.5T is 83.10%. From Fig. 14 shows a 3<sup>rd</sup> order harmonic factor of CRNGO material is higher than 3% SiFe (CRGO) at 0.2T is 16.63%.

The 3<sup>rd</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) at 0.5T is 83.10%

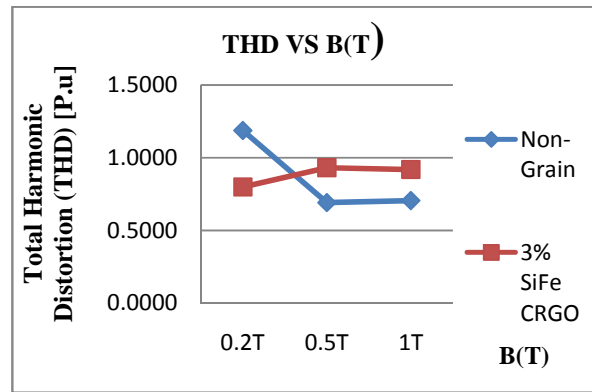


**Fig. 13:** Comparison of 3<sup>rd</sup> order Harmonic Factor between CRNGO and 3% SiFe CRGO

The 3<sup>rd</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) at 1T is 47.44%. Comparison of 3<sup>rd</sup> order harmonic factor effect is highest on both materials occurs at 1T. Effect of harmonic current is highest at 0.2T for CRNGO material and for 3% SiFe (CRGO) is at 0.5T. From Fig. 17 shows a 5<sup>th</sup> order harmonic factor of CRNGO material is higher than 3% SiFe (CRGO) at 0.2T is 63.02%.



**Fig. 14:** Comparison of 5<sup>th</sup> order Harmonic Factor and 3% SiFe CRGO



**Fig. 15:** Comparison of THD between CRNGO between CRNGO and 3% SiFe CRGO

The 5<sup>th</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) at 0.5T is 20.18%. The 5<sup>th</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) at 1T is 18.38%. Comparison of 5<sup>th</sup> order harmonic factor effect is highest on both materials occurs at 0.2T. Effect of harmonic current is highest at 1T for CRNGO material and similarly for 3% SiFe (CRGO).

From Fig. 15 shows a THD of CRNGO material is higher than 3% SiFe (CRGO) at 0.2T is 32.7%. The THD of CRNGO material is lower than 3% SiFe (CRGO) at 0.5T is 34.67%. THD of CRNGO material is lower than 3% SiFe (CRGO) at 1T is 30.34%. This thing happened because if refer to B-H curve for both material that in 0.2T the domain material of 3% SiFe shows not excited yet. While in 0.5T shows the domain material of Amorphous ribbon is in under operation and domain material of 3% SiFe is not operate yet. At 1T, the domain material of Amorphous ribbon is near to saturation but for domain material of 3% SiFe is not in saturation yet.

#### Summary:

Harmonic content is an important factor that influence on transformer losses. The 3<sup>rd</sup> order harmonic factor of CRNGO is lower than 3% SiFe (CRGO) about 83.10%.at 0.5T. The 5<sup>th</sup> order harmonic factor of CRNGO material is lower than 3% SiFe (CRGO) about 20.18%. at 0.5T. The THD of CRNGO material is lower than 3% SiFe (CRGO) at 0.5T is 34.67%. It does mean the harmonic effect caused by different induced current and different ingredient material.

#### ACKNOWLEDGEMENT

This work is financially supported by the FRGS Grant Fasa 2/2010/9003-00286 and FRGS Grant 2012/9003- 00347.

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