Amorphous Transformer: Study Paper

Vaibhav Ware[1], Ganesh Dungahu[2], Tukaram Arade[3], Anil Tekale[4], Swapna God[5]
[1, 2, 3, 4, 5] Dept of Electrical Engineering
[1, 2, 3, 4, 5] H.S.B.P.V.T's GOI, COE Kashti, Maharashtra, India

Abstract- *In distribution transformer design, main stress is to reduce core losses. To reduce core losses in distribution transformer cold-rolled grain oriented (CRGO) steel is preferred by manufacturers. Amorphous material has very less core losses compared to CRGO steel, therefore it is being seen as a good substitute of CRGO steel. Now-a-days some manufacturers are using amorphous material in miniature and medium size transformers in place of CRGO steel. The cost of amorphous core transformer is higher than the cost of CRGO core transformer. Here an effort is being made to reduce the cost of amorphous core distribution transformer by using a 'CRGO-Amorphous' core in place of amorphous core. A comparison is being presented here among 'CRGO core distribution transformer (CCDT)', 'amorphous core distribution transformer (AMDT)' and 'Amorphous-CRGO core distribution transformer (AMCCDT)', in terms of cost and efficiency.*

Keywords- Transformer , amorphous core, CRGO core etc…

I. INTRODUCTION

Distribution transformers are used for distribute the electrical power in residential, industrial and agriculture areas

1. Distribution transformers are energized for twenty four hours with load, therefore they are designed to have low no-load losses
2. Under no-load condition only core losses occur in a transformer and copper losses are negligible. therefore no-load losses are also called core losses for a transformer. Now-a-days CRGO steel is being used in distribution transformers for which allowable limit of flux density is up to 1.55 Tesla for low core losses
3. If a distribution transformer with CRGO core is designed above 1.55 Tesla then certainly the cost of the transformer reduces but performance deteriorates in terms of efficiency. There has been constant search for transformer core materials, which may have the least loss. Iron-Boron- Silicon Amorphous alloy has evolved as the low loss material for distribution transformers
4. **[4a].** Molten metal when cooled to solid state at a very high rate retains a random atomic structure which is non-crystalline. This metal is called amorphous. This resembles with glass and is also referred as `glass metal'. Need to achieve the required cooling rate restrict the thickness of the metal to 0.025 mm i.e., almost 1/10th of the thickness of conventional CRGO steel. Due to low saturation limit (1.5 Tesla) in amorphous core, larger core and consequently larger coils and tank size are required as compared to CRGO core transformers. The problem has been overcome to some extent with the development of amorphous metal strips. This is achieved by compacting number of thin ribbons. This strip is commonly known as `POWER CORE'. Amorphous strips are four times harder than CRGO steel. Hardness along with reduced thickness makes slitting and shearing difficult. The brittleness property of amorphous metal has also made it un-friendly to the transformer manufacturers. Due to these limitations, the amorphous core technology has been limited at present to very few customers in India and abroad

   [4b]. Amorphous metal core has some merits; the non-crystalline structure and random arrangement of atoms gives low field magnetization and high electrical resistivity. Due to low field magnetization, hysteresis loss is low and due to high electrical resistivity eddy current loss is suppressed. As such core losses of amorphous metal alloys get reduced by 42 per cent and magnetizing current by 53 percent. The most attractive characteristics of amorphous alloy are obviously its extremely low core loss and low magnetizing current. The amorphous metal saturates almost at 1.5 Tesla.
5. whereas CRGO steel saturates at almost 2.03 Tesla. Overall cost of amorphous core transformer is approximately 20 to 30 percent higher than conventional CRGO core transformers [4a]. In past, some efforts have been made to reduce the cost of CRGO core transformer by preferring 'circular multi-stepped' cross-section of CRGO core in place of 'rectangular' cross-section.
6. For 'circular multi- stepped' cross-section of core, the mean length of winding turn reduces, so mass of copper used in winding reduces; therefore cost of transformer reduces because of reduction in the cost of winding. The manufacturers of amorphous core distribution transformers are very limited in the world because of two reasons, one is its high material cost and another is its brittleness property. Because of limitation of its brittleness property, in amorphous core transformers

manufacturers are using square or rectangular cross-section of the core.

7. Over transformer design Amorialis et al.
8. have reported a huge literature survey of 425 papers. Till now no more work has been reported to reduce the cost of amorphous core distribution transformer. Here an effort is being made to reduce the cost of amorphous core distribution transformer by using a 'CRGO-Amorphous' core in place of amorphous core. A comparison is being presented here among 'CRGO core distribution transformer (CCDT)', 'amorphous core distribution transformer (AMDT)', and 'Amorphous- CRGO core distribution transformer (AMCCDT)', in terms of efficiency and cost. The task of a designer is to make a proper compromise between cost and performance.

II. WHAT ARE AMORPHOUS METALS ?

- Amorphous metals are made of alloys which have no atomic order.
- The random molecular structure of amorphous metal causes less friction than SiFe ,when a magnetic field is applied.
- This unique property allows for greater ease of magnetization and demagnetization and significantly lowers hysteresis losses in amorphous metals.
- In addition, amorphous metals have very thin laminations, resulting in lower eddy current losses when compared to SiFe.

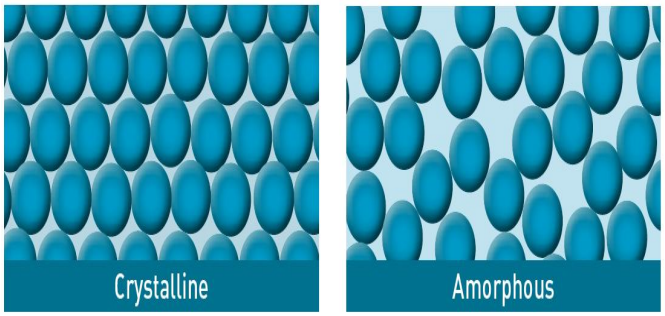

Fig -1: Difference between the crystalline & Amorphous.

2.1. Properties Of Amorphous Metal

- Amorphous metallic alloys have excellent soft magnetic properties:
- low magnetic loss.
- High electrical resistivity of the alloy.
- Amorphous metals stay elastic in high tension rates.
- Better tensile strength than tool steels.
- Amorphous metal with chromium has good corrosion durability.

Table -1: Amorphous alloys

Material	alloy composition	losses (20kHz, 200mT) [W/kg]	saturation B_{sat} [mT]	magneto-striction λ_s [10^{-6}]	permeability (50Hz) $\mu_4 - \mu_{max}$	max. working temp. [°C]
grain oriented **Silicon steel**	$Fe_{97}Si_3$	> 1.000	2.000	9	2.000-35.000	~ 120
standard crystalline permalloy I	$Ni_{45}Fe_{55}$	> 150	1.550	25	12.000 – 80.000	130
standard crystalline permallo y II	$Ni_{54}Fe_{46}$	> 100	1.500	25	60.000-125.000	130
advanced Silicon steel	$Fe_{93,5}Si_{6,5}$	40	1.300	0,1	16.000	130
Fe- amorphous alloy	$Fe_{76}(Si,B)_{24}$	18	1.560	27	6.500 – 8.000	150
high performance **ferrite**	MnZn	17	500	-	1.500 – 15.000	100/120
advanced crystalline permalloy	$Ni_{80}Fe_{20}$	> 15	800	1	150.000-300.000	130
Co-amorphous alloys a	$Co_{73}(Si,B)_{27}$	5,0	550	< 0,2	100.000-150.000	90/120
Co-amorphous alloys b	$Co_{77}(Si,B)_{23}$	5,5	820	< 0,2	2.000 – 4.500	120
Co-amorphous alloys c	$Co_{80}(Si,B)_{20}$	6,5	1.000	< 0,2	1.000 – 2.500	120
nanocrystalline alloys I	FeCuNbSiB	4,0	1.230	0,1	>20.000 -200.000	120/180
nanocrystalline alloys II	FeCuNbSiB	4,5	1.350	2,3	>20.000 -200.000	120/180
nanocrystalline alloys III new	FeCuNbSiB	5,0	1.520	7,2	~ 10.000	120/180
		Evaluation of figures:	good	standard	poor	

III. WHAT ARE AMORPHOUS METAL CORE TRANSFORMERS?

- In transformers with amorphous cores, a ribbon of steel is wound forming the core.
- The big benefit of amorphous metal core transformers is that amorphous steel has lower hysteresis losses.
- Because there is no rule of atomic arrangement, the energy loss (hysteresis loss) is small when the flux of magnetic induction passes the iron core.
- In addition, eddy current loss is decreased because the thickness is approximately 0.03 mm, which is about 1/10 comparing with silicon steel.

IV. WHY THE AMORPHOUS METAL CORE TRANSFORMERS USE ?

Core losses are present in the transformers even when they are under no-load conditions; in addition, the load factor is very low.

Put together up to 3% of all electrical power generated is wasted through transformer losses nation & worldwide.

Two types of energy losses are inherent in the running of distribution transformers: Load losses (copper losses) that vary depending on transformer loading, and no-load losses (iron losses) that occur in the magnetic.

When this is replaced by amorphous metal, the core loss of the transformer is reduced by as much as 75%.

V. MERITS OF AMORPHOUS METAL CORE TRANSFORMERS

- Up to 75% energy saving
- Reduced CO2 and SO2 emission
- Reduced magnetizing current
- Reduced temperature rise of core

- Cumulative saving of energy cost
- provides the key to improve utility economics and enhancing energy saving efforts

VI. DEMERITS OF AMORPHOUS METAL CORE TRANSFORMERS

- Material is very thin 0.03 mm making Difficult to handle.
- Repair at site is not possible
- Only 23 suppliers in India for Amorphous core.
- Amorphous is Brittle & requires extreme care During assembly, not suited for robust use.
- Specialized equipment need to prepare & assemble cores

VII. CONCLUSIONS

Amorphous core transformers are energy efficient transformers with increased cost. The cost of the transformer can be reduced by replacing the amorphous core with Amorphous-CRGO core

REFERENCES

[1] Martin J. Heathcote. 1988. J and P Transformer book. Oxford university press.
[2] Say M.G. 2005. Performance and Design of AC Machines, CBS publishers India.
[3] Transformers by BHEL. 2009. Tata McGraw Hill publication.
[4] Websites: a) http://www.kotsons.com
b) http://www.metglas.com