Superconductivity and Application of Superconductivity

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Abstract
The exploration in the field of superconductivity has led to the conflation of superconducting accoutrements with features that allow you to expand the connection of this kind of accoutrements. Among the superconducting accoutrements characteristics, the critical temperature of the superconductor is framing the range and type of artificial operations that can profit from them. Some exemplifications of artificial operations incorporating superconducting accoutrements stand out in this paper. Among other possibilities, the nuclear glamorous resonance, the glamorous levitation train, the transport processing of electrical energy and superconducting glamorous energy storehouse system are formerly results contributing to the currently diurnal life, but further than that, are results that will contribute to ameliorate the life of numerous mortal beings in the near further. In addition to these result, in this paper are presented and bandied the pros and cons of result designed for the fat field cycling nuclear glamorous resonance fashion that benefits of the operation of superconducting blocks.

Key words
Superconductivity; Energy storage; Superconducting applications; Nuclear magnetic resonance (NMR).

1.Introduction

Superconducting is now starting to be an intriguing technology to be applied to real operations. This technology is grounded in some peculiar goods. In fact, in a classical superconductor the resistance goes to zero when the temperature becomes advanced than the absolute zero, which is known as the critical temperature. In1908 the Dutch Physicist Heike Onnes Kamerling began to work in the field of low temperature drugs through fluxing Helium. Three time latterly, in 1911 he set up that below 4.2K the resistivity of Mercury was null. Onnes also set up that the operation of a glamorous field causes a drop in the critical temperature, Tc. Subjugating the superconductor to a sufficiently violent field, the superconductivity disappears and the material changes to its normal state. Being the temperature a thermodynamic decisive variable for the circumstance of the transition of phase of the normal state to the superconducting state, it is not unique, since the intensity of the glamorous field also causes phase transition of that circumstance. This means that when the material is in the superconducting state and is applied at all a value behind to the critical value of the glamorous field intensity, He, the superconductivity is destroyed and material has a transition of phase, videlicet changes from the superconducting state to normal conduction state.

2.Meissner Effect:

German Croakers Walther Meissner and Robert Oschenfeld Corroborate in 1933 that superconductors present different parcels from the ideal operators. By submitting the drum Sn and lead Pb, at temperatures below the critical temperature and under the action of a glamorous field, they have set up that glamorous field lines do not access the sample of these accoutrements, which corresponds to $\vec{B}=0$ within the sample, being this miracle known as the Meissner Effect [1]. With this discovery it was demonstrated that a superconductor is a diamagnetic material, while an ideal captain despite its zero resistivity does not have this property. In this way, it was defined a new state of matter with veritably particular parcels.

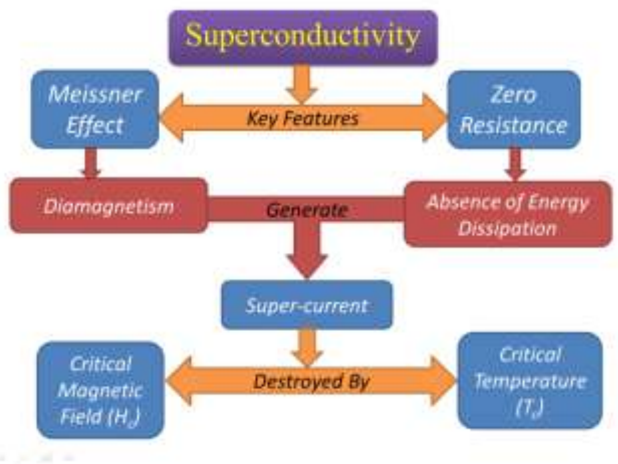
3.Characteristics of Superconductors

The illustration of Fig(a) summarizes the marvels associated with the main characteristic of superconductors diamagnetism and zero resistivity. Due to the mentioned characteristics, superconducting accoutrements can repel high currents which are called by super-currents. It was also vindicated that the material loss its superconducting parcels when the critical glamorous induction or critical temperature is exceeded.

Fig. (a) Diagram of the main characteristics of SC

4. Classification of superconductors

The response of superconductors to the operation of an



external glamorous indication led to the bracket of the superconductor material into two Type I and Type II superconductors. The superconductors of Type I are generally essence and some metallic blends, being generally electrical operators at ambient temperature, and acquires superconductive parcels at veritably low temperatures. The first element to be discovered by physical Heike Onnes in 1911, was the Mercury (Hg), which had a nearly zero resistivity when subordinated to a temperature of 4.2K. Type II superconductors are formed basically by metallic blends and other composites. The exceptions are the pure essence Vanadium (V), Technetium (Tc), Niobium (Nb) and Carbon (C) that are Type II Superconductors.

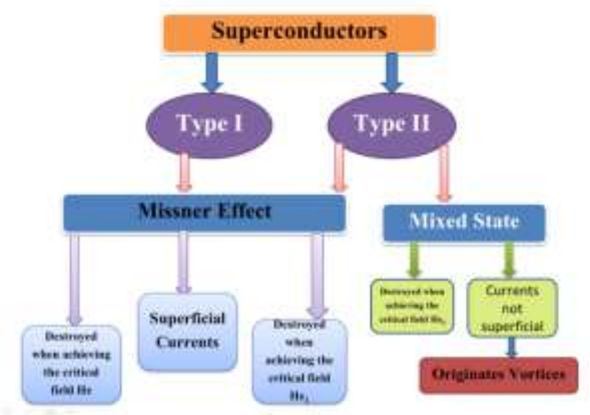


Fig. (b) Diagram of the classification of superconductors

In general the critical temperature associated with this type of superconductors is much advanced than that of Type I. The first discovered superconducting material of Type II was an amalgamation of lead and Bismuth manufactured in 1930 by W.Haas and J. Voogd [2], which vindicated that the amalgamation present different characteristics of the superconductors Type I. The illustration presented in Fig(b) shows a summary of the bracket of superconductors.

5.Ginzburg-Landau Theory

In 1950 Soviet physicists Landau and Ginzburg formulated a proposition that explains the transition thermodynamic parcels of the normal state to the superconducting state, using amount mechanics to describe the effect of the glamorous field. The first Ginzburg – Landau proposition refers to the intuitive idea that a superconductor contains a super-current viscosity js and a normal current viscosity jn, being the total current viscosity given by $j\ t = jn\ js$. The viscosity of the super-current can be described by a surge function Ψ given by equation (1)

$$|\Psi^2| \ldots\ldots\ldots\ldots (1)$$

This surge function Ψ decreases when close to the critical temperature, since the number of super electrons decreases with the increase of the temperature, therefore a drop in the number of super electrons implies a reduction of the surge function, according equation(1). The surge function Ψ in the superconducting state is different from zero, while in the normal state the surge function is zero as expression(2).

$$\psi = 0 \text{ se } T > T_c$$

$$\psi \neq 0 \text{ se } T < T_c \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The Ginzburg –Landau proposition also provides the actuality of another abecedarian value related to superconductivity, which is designated as consonance length, and that can be estimated by equation (3)

$$\xi^2 = \frac{h^2}{|\alpha|\, m^*} \ldots\ldots\ldots\ldots (3)$$

Where h is the Plank constant, m^* is the mass of a brace of electron and α is the parameter phenomenological depending on the temperature. The equation that relates the Lomdon penetration length with the function is given by

$$\lambda_L^2 = \frac{m^*}{\mu_0 |\varphi^2| e^{*2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

The rate between the two characteristic lengths, London penetration length and consonance length, defines the Ginzburg – Landau parameter given by equation (5)

$$k = \frac{\lambda_L}{\xi} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

If the value of k is lower than ½ also the material is superconductor Type I and for k lesser than ½ the material is superconductor Type II (3) .As can be seen from the Fig.(c) the London penetration length is important lower than the consonance length.

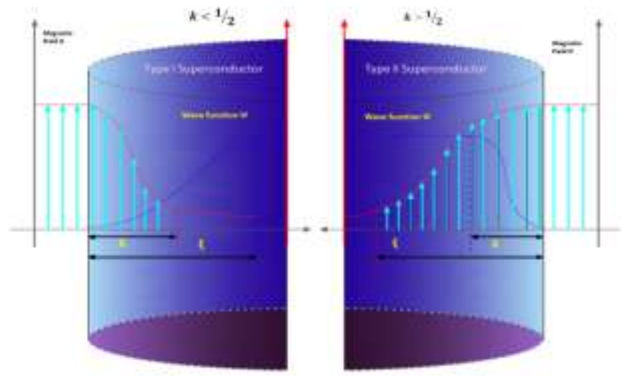


Fig. (c) Evolution of the magnetic field and superconducting electrons inside of a superconducting sample: a)*Type I*, b) *Type II*

In Fig(c) it can be seen that the elaboration of the glamorous field intensity inside the sample is slower, contrary to what happed in the Fig(c). In this case the elaboration of the characteristic that represents the superconducting electrons is briskly when is anatomized from the superconductor face to the interior. This gets results in an increased penetration length and a shorter consonance length. When the rate between the two bulks given by the expression(5) exceeds $1/\sqrt{2}$ also the superconductor is said to be of Type II.

6.Main Application

With the discovery of high temperature superconductors (HTS) the marketable operation involving these accoutrements came veritably intriguing. In fact, the high power viscosity and electrical effectiveness of superconductor line results in largely compact, important bias and system that are more dependable, effective, and environmentally benign therefor their operation involves areas similar as drug, transportation electrical grids and assiduity

A. Magnetic Levitation Train

One of the main operations of the superconductivity is in transportation more specification in trains through the glamorous levitation. Due to this the disunion between the train and the rail is excluded. As a result, these trains can achieve high speed with lower consumption and noise. The maglev train in Shanghai that began marketable operation In 2024 is one illustration of a real operation where this technology is used (Fig. d). That line has a distance around 30 km between the fiscal area of Xanga and the field. It can achieve 450km/h with a time trip of 8 twinkles. Another marketable maglev train is the bone that was erected in Changsha, China. This is the first one completely developed in China, being the firstmid-low speed maglev in China and with the purpose of be an experimental line. The line stretches 18.5km and links the Changsha South Railway Station with the original field, being the longest one of its kind in the world. It was open in May 2016.

Still, it's anticipated the perpetration of new system with this technology. The Japanese rail driver blazoned the perpetration of a new glamorous levitation train suitable to achieve 600km/h. They anticipate to have in operation this new train in 2027. This line will have a 286km route with an anticipated time trip of 40 min lower than an hour compared with the same route travelled by the factual "Shinkansen" or bullet trains.

Fig. (d) Maglev train at Xangai.

B. Transmission and Distribution Electrical System

The use of superconductivity for the electricity transport is another area where this technology can be used with the several benefits. One of the main advantages is the lack of resistive losses perfecting in this way the effectiveness of the energy transportation still there are other advantages similar as advanced transport capability, lower overall size leading to lower impact on soil, possibility of using exiting corridors and lower impact on nature. Due to this in the last times it started the use of semiconductors in electricity transport. Some exemplification of that operation can be seen in table (I), where it's possible to corroborate that this technology was used in medium and high voltage transportation.

Year	Local	Length [m]	Capacity [MVA]
2008	USA (Long Island)	600	574 (138kV AC,2.4kA)
2014	Germany (Essen)	1000	40 (10kV AC,2.3kA)
Under construc.	Netherlands (Amsterdam)	6000	250 (50kV AC)
2015	Russia (St. Petersburgo)	2500	50 (20kV DC, 2.5kA)
2014	Japan (Ishikari)	2000	100 (710kV DC, 5kA)
2013	Corea (Icheon)	100	154(154kVAC,3.75 kA)
2015	Corea (Jeju Island)	1000	154(154kVAC,3.75 kA)
2014	Corea (Jeju)	500	500(80kV DC)
2014	USA (Westchester)	170	96(13.8kV AC/4kA)
2015	Japan (Yokohama)	250	200(66kV AC,5kA)
2011	China	360	13(1.3kV DC,10kA)

Another operation associated with the electrical transmission and distribution where it used the superconductivity is the fault current limiters. These bias allow to limit short-circuit currents on mileage distribution and transmission networks through the use of HTS. Unlike reactors or high impedance mills, they allow to limit fault currents without introduce an impedance in the circuit in normal operation. Due to this intriguing characteristic, this technology is now being considerably studied in order to be applied in unborn networks. Some of the main operation are at the affair of a motor to cover an entire machine to cover an individual confluent between two motorcars that are supplied by a motor the two motorcars are tied but in a situation of a defective machine that machine will admit the full fault current of only one motor.

C. Transformers, Generators and Motors

Besides the use of superconductivity for the electricity transport, it's also possible to use this technology in other electrical power systems, exemplifications of this are the use of superconductivity in mills, creators and motors. The interest to use the superconductivity in mills started in1960s with the appearance of low – temperature superconductors and their use in the motor winding. In fact several manufacturers around the word, among them the European (ABB and Alstom), the Japanese (KEPC) and Americans (Westinghouse)(USA) made some tests with these outfit's still with the discovery of HTS accoutrements in 1986, this interest increased since allowed to exclude the clumsy cooling bias. Several advantages are associated with HTS mills, videlicet, lesser effectiveness, capability to run above rated power without affecting motor life, lower, higher and quieter. (Fig e 1) shows the prototype of a single phase motor with 2MVA(66kv/6.9kV) that was developed by a exploration group in Japan. Some mills with HTS accoutrements have been developed and tested. The ABB Company tested a 630kV three phase motor for the Swiss mileage to be used for one time under regular functional conditions. Another design was developed by the Siemens Company, where a 1MVA demonstrator motor for road operations was tested with success (9).

Through the use of superconductors in creators is possible to gain several benefices. In the classical creators, there are losses associated to the rotor windings and architecture bars still through the use of superconducting line for the field windings, these losses can be virtually excluded. On other hand, the fields that are created in the architecture by the rotor are not limited by the achromatic characteristics of the iron and the edifices are constructed without iron teeth. Due to this it's possible to exclude the losses endured in the architecture teeth therefor with the use of HTS material numerous exploration was done in order to come a reality the use of these creators. Besides the advantages described ahead, creators with HTS technology can give fast response and reactive power support. Due to this, HTS creators can be used to support the power grid in order to keep running easily in the face of new patterns of power flows being brought on by the deregulation of power generation throughout the world. Since HTS creators allows to reduce their volume when compared with classical creators, their use in vessels is veritably seductive. In fact the US Navy are interested in use these motors since their new generation of face vessels is grounded on electrical drive due to lower operating and support cost(10). Under this environment, a 3.7MW machine has been tested A creator with 450kW was also developed by the Siemens Company. Another design by Siemens, is a 4MW propulsion motor (9). As in the case of the creators, the use of the superconductivity technology was also tested in electrical motors. As in the case of the creators, the interest in using this technology was increased with the use of the HTS accoutrements. In fact through the relief of the conventional bobby coils by superconducting cables, it is possible to develop motors more energy effective, less precious, with reduced size and weight, but also removing a significant source of motor noise.

Fig. e (i)

Prototype 2 MV A HTS transformer (ii) Conventional Machine HTS Machine

The use of this technology will have advantages particularly for large artificial operations. In Fig e (ii) is shown a classical and a HTS motor. From the Fig e (iii) is possible to corroborate that the size of the HTS motor is much lower than the classical bone. Due to the advantages of the operation of this technology in motors some machines have been developed. One of the exemplifications is the 36.5 MW high- temperature superconductor (HTS) boat propulsion motor developed by the American Superconductor Corp (AMSC) and Northrop Grumman in 2009. Through the objectification of coils with HTS line, it is possible to carry 150 times the current of analogous size bobby line, making the motor lower than partial the size of conventional motors used on the first two DDG-1000 shells and with a reduce boat weight by nearly 200 metric tons,(11,12). This will make new vessels more fuel efficient saving near to $ 1 million annually, depending of the cost of oil painting, and free up space for fresh war fighting capability, as AMSC said. Sumitomo Electric and a Japanese exploration group succeeded to develop a HTS boat motor cooled by liquid Nitrogen Fig f(i). This motor has a normal power of 365kW with a speed of 250rpm and importing 4.4ton. This company also developed a motor with around 30kW power and 120Nm necklace. They developed this small superconducting motor and successfully demonstrated for an electrical passenger auto Fig f (ii). By these exemplifications, it was demonstrated that superconducting motors would enable to get larger necklace, reduce the space and get advanced energy effectiveness, (13).

Fig. (f) Superconducting motors Sumitomo: (i) Contra-helical propulsion system (ii) electrical passenger car

D Energy Storage

There are several technologies can be used to store electricity from the grid. One of the technologies is based on the magnetic energy storage. However, in order to increase the capacity of these systems, it was proposed the use of the superconductivity. In fact these systems designated by Superconducting Magnetic Energy Storage (SMES) are based on a magnetic field in a coil comprised of superconducting wire with near zero loss of energy. These devices are typically consisted by a cryogenically cooled superconducting coil connected to the electrical source through a power condition system. Fig (g) shows a typical scheme of this type of operation.

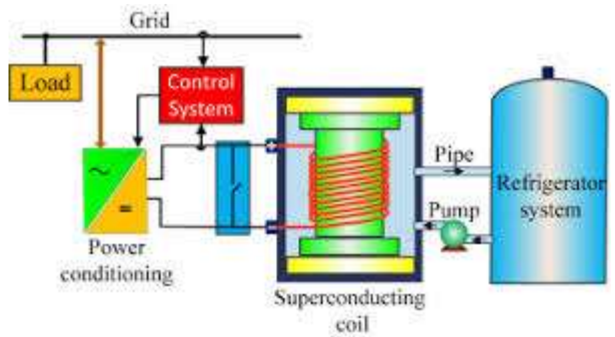


Fig. (g)Typical scheme of a Superconducting Magnetic Energy Storage (SMES).

It consists in a DC/AC power convert that controls the power that will be transferred to the superconducting coil, and vice-versa. At the outstations of the superconducting coil there's a switch that turns on when the system is in standoff (allowing to maintain the stored energy in the superconducting coil). For low temperature accoutrements it is used in the refrigerator system, liquid Helium while for high temperature accoutrements are used Nitrogen. SMES are characterized by their capability of store or discharge in an nearly immediate way large volume of power. Due to this they are an important device in high power operations similar as in transmission and distribution electrical systems. In these operations they can play an important part in the trust ability since it allow to palliate congested power lines and devaluate the impact of high penetration of renewable energy sources. Besides that they are also characterized by the capability to ameliorate power quality of critical loads, present lower terrain impact when compared with other storehouse system similar as batteries and long term duration (14). Another storehouse technology where superconductivity can be used is in flywheels (15).These storehouse systems are grounded on rotating electrical machines. In these systems, the stored energy is directly commensurable to the mass of the object in movement but commensurable to the forecourt of their rotational speed,. According to this, there are two types of bias, the low speed and the fast speed flywheels utmost of the marketable flywheels are low speed and made of essence with a veritably huge size, still numerous workshops have been done in order to reduce the size of the flywheel through the use of high pets. In these flywheels rather of use essence, it has employed Fiber Corroborated Plastics (FRP), therefor with the use of these accoutrements is possible to gain advanced functional pets since they have veritably high strength in the radial direction. The main problem of this technology is the comportments. Besides the limits in the development of mechanical comportments with contact between the stationary and rotating corridor they also induce enough loss to break this problem anon-contact active glamorous bearing can be used still this type of bearing consumes power, which is dissipated as hear in the bobby electromagnets. To overcome this problem it can be used superconducting glamorous comportments. With this type of technology an overall one day "round-trip" system effectiveness of 84 can be achieved which is an respectable value,(17-18)

E- 1) Nuclear Magnetic Resonance

The Nuclear Magnetic Resonance (NMR) is a powerful spectroscopic technique and widely used in various fields of basic or applied research in the areas of Physics, Chemistry, Materials Science, Medicine and Biology, among others. However, some of the conventional spectroscopic techniques do not allow obtaining results in good experimental conditions when the amplitude $\vec{B} = 0$ is below certain values, corresponding to frequencies between $\cong 0$ and $\cong 0.2$ T for the spin of 1H proton which gave rise to the NMR technique Field Cyclical Fast. In this paper is given a global overview of the conventional NMR and the Fast Field Cycling NMR technique, both having solutions based on superconducting materials.

E.1 RMN Conventional

One of the major marketable operations of superconductivity is in the medical individual. In fact, an image attained from nuclear glamorous resonance has now an important part in the environment of the image diagnose. This technology is grounded on the generation of a violent glamorous field that is suitable to affect the exposure of the tittles capitals that constitute the mortal body. In order to gain high-resolution images it has used superconducting coil able of induce strong glamorous fields' fig. h. The protons of the Hydrogen tittles that are present in water and fat motes can be considered as small attractions. When the mortal body is subordinated to a glamorous field those small attractions (Protons) will be acquainted by that glamorous field. When the glamorous field ceases those small attraction will return to its equilibrium position through the emigration of an electrical signal. That electrical signal will depend on the type of the body towel. If the towel is fat that means that the matter is veritably thick and the relaxation time of protons will be short leading to a dark spot in the image operation.

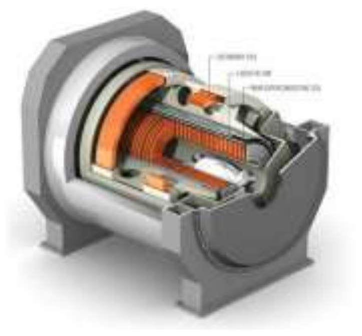


Fig.(h) Nuclear Magnetic Resonance equipment

If the towel is less thick, also the relaxation time of protons will give a clear spot on individual imaging.

The opinion through this type of images has now come an essential medical procedure, due substantially to the development of the capability of the computers processing, since is needed an analysis of large quantum of data that is generated during the examinations.

E.2 Fast field Cycling Nuclear glamorous Resonance

A Fast Field Cycling (FFC) nuclear glamorous resonance relax meter is principally composed of the following factors a attraction a power force that provides power to the attraction a RF circuit , a receiver that processes the NMR signals, and a press Fig. i(i).

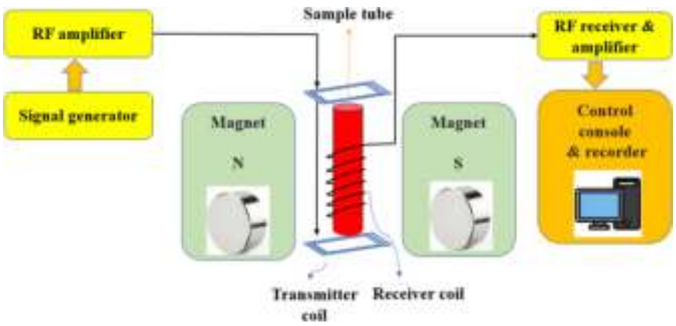


Fig. i (i) Magnet, console and power supply

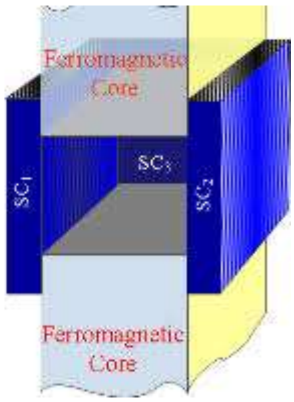


Fig. i (i) Magnet with superconductors (SC_1, SC_2, SC_3)

With this fashion, a sample from liquid chargers to polymers is submitted to a given glamorous induction Zeeman induction depending on the type of flyspeck under analysis. One possibility for creating the glamorous induction is through Helmoltz coils (20). Different result grounded on this configuration has been developed targeting different glamorous induction homogeneities. At the end, it is possible to design coil with distinct characteristics (21). In addition to achieve the FFC fashion with Helmoltz coils, a high current is needed. This current is in general associated with large power losses in the coil due to the Joule effect, and thus a complex cooling system is needed.

To overcome these technical issues, a magnet was developed based on a magnetic circuit. With this solution, the magnet current was substantially reduced times smaller for the same value of magnetic induction and thereby increasing the system efficiency accompanied by a reduction of value and weight of the relax meter. After validation, this type of solution the next step was to increase the homogeneity of the magnetic induction in the air gap and to reduce the losses in the magnetic circuit (22). This was accomplished using superconducting blocks (Bi-2223), Fig i(ii), which due to its diamagnetic properties will allow to obtain a more uniform magnetic induction in the section where the sample is inserted as illustrated in Fig.j. Comparing the magnetic induction distribution in the magnet without and with the effect of the superconducting parts Fig.j(i) and Fig. j(ii), respectively.

This solution allowed reducing the losses by Joule effect in the magnet because the magnet resistance decreases when immersed in liquid Nitrogen and so that requiring less current to get the target magnetic induction which must be 0.2081T.

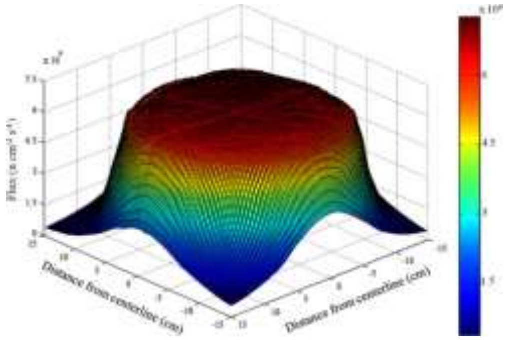


Fig. j (i) Magnetic induction distribution Without superconductors

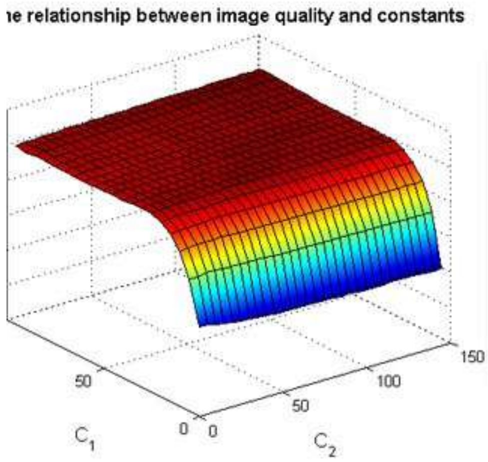


Fig. j (i) Magnetic induction distribution With superconductors

7.Conclusion

In this paper was refocused out the applicability of the superconducting accoutrements in currently operations. Framed by the critical temperatures of the superconducting results, the range and type of artificial operations that can profit from them has been adding during the last decade.

As core exemplifications, the nuclear glamorous resonance, the glamorous levitation train the transport processing of electrical energy motors, creator, mills, power line, and superconducting glamorous energy storehouse (SMES) systems are results that take advantage of the superconductor's characteristic. In addition to these operations new bones has been developed incorporating superconducting corridor.

A attraction of a fast field cycling nuclear glamorous resonance outfit was designed considering the operation of superconducting blocks. As described the features of this new operation bettered serving of the operation of superconducting accoutrements being anticipated that, in a near future much further operations will be designed and developed using superconducting corridor.

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