INSTALLATION OF SKEW SEXTUPOLE MAGNETS AT KEKB

M. Masuzawa, K. Egawa, T. Kawamoto, Y. Ohsawa, T. Sueno, N. Tokuda,
KEK, Tsukuba, Ibaraki, Japan

Abstract

A new set of magnets, the skew sextupole magnets, were designed, manufactured and installed in the KEKB tunnel during the three month shutdown of January, February and March, 2009. Twenty magnets were installed in the HER and eight magnets were installed in the LER, respectively. The skew sextupole magnets are used to correct for the chromatic X-Y coupling at the interaction point (IP). A significant luminosity boost was achieved. The skew magnet parameters and the field measurement results are described in this report.

MAGNET DESIGN

Recently, from the results of computer simulation with beam-beam interactions[1,2], it was found that large chromatic X-Y coupling at the IP deteriorates the luminosity. A correction scheme of chromatic X-Y coupling at the IP using skew sextupole magnets was proposed. Since the request for installing a new set of magnets was made just before the shutdown, the entire process of the magnet design and production needed to be simplified and optimized.

The magnet parameters were optimized so that the magnets can be operated using spare power supplies. Polyester enamelled copper (PEW) wires, which were used for the KEKB solenoid magnets for mitigating the electron cloud instability in the LER, were used. The number of turns was determined by the specifications of the available bipolar power supplies. The magnet bore needed to be large enough so that the cooling channel of the existing vacuum chamber fits. The length of the magnet was determined by the space available in the beam line. The pole has the basic sextupole equi-potential curve without any modification to the pole shape. Spare magnet supports for the corrector magnets were recycled as magnet supports for the skew sextupole magnets with some modifications. Table 1 summarizes the basic magnet parameters.

Table 1: Magnet Parameters

Magnet bore diameter	160 mm
Magnet length	200 mm
Pole width	50 mm
Magnet core weight	80 kg
Wire diameter	2.0 mm, including insulation
# of turns/pole	100
# of layers/pole	6
B" at I = 10[A]	14.7 [T/m^2]

MAGNET PRODUCTION

The pole pieces with coil wound on them are shown in Fig.1. One hundred turns of wire were wound on the pole in six layers at KEK. A thin polyimide sheet was inserted between each layer. The electrical insulation was checked for all the coils when wire winding was completed. The poles are bolted on to the magnet frame as in Fig. 2. Figure 3 shows the front and side views of the complete skew sextupole magnet. As the current density in the wire goes as high as several A/mm^2 at I=10 A, the temperature was monitored at the inner and outer sides of the coil. The results are shown in Fig.4. The coil temperatures stayed well below 80 degrees, which is much below the maximum specified operating temperature of ~150 degrees for PEW.

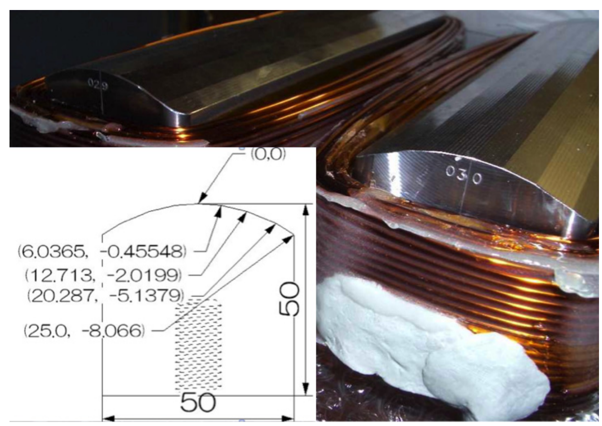

Figure 1: PEW wires wound on the poles. The dimension of the pole is also indicated.

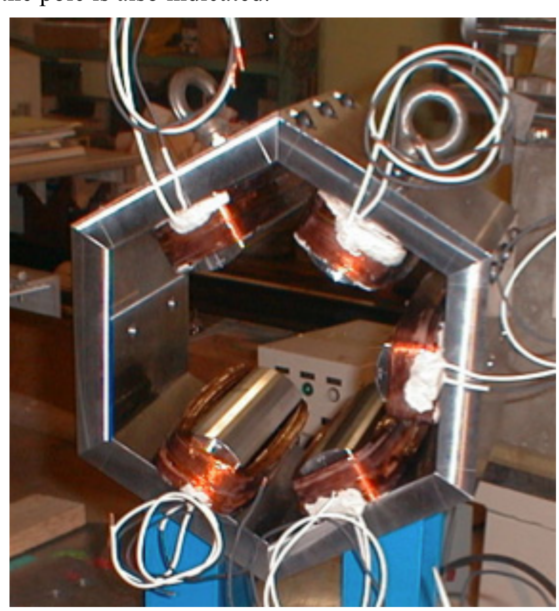

Figure 2: Magnet coil and yoke assembly. The poles are bolted on the magnet yoke.

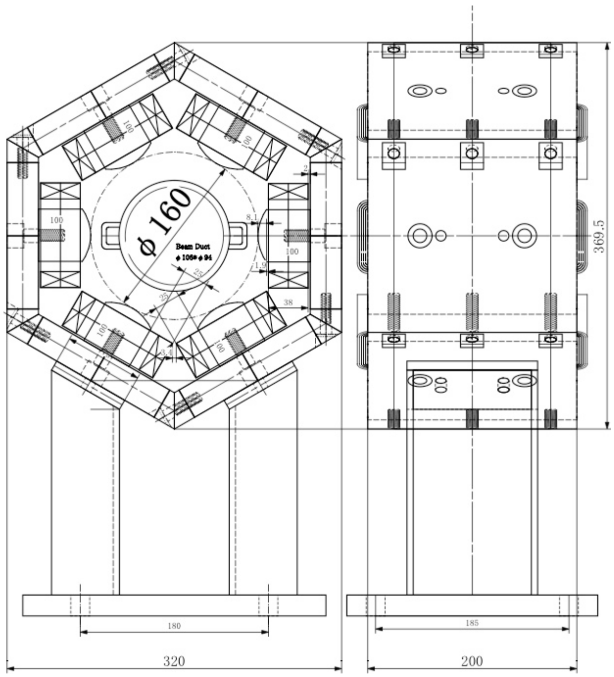

Figure 3: Skew sextupole magnet front and side views.

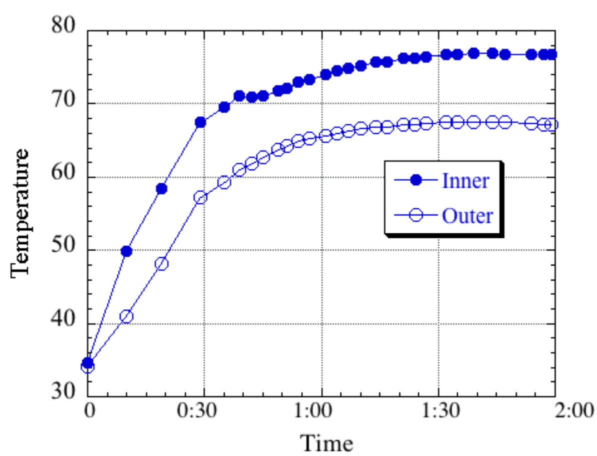

Figure 4: Temperature monitors on the inner side (solid circles) and outer side (outer circles) of the coil when operated at $I = 10$ A.

FIELD MEASUREMENT

The magnetic properties were measured using a rotating coil. Figure 5 shows the excitation curve of the first magnet. The data were taken only up to $I = 8.2$ A due to a limitation on the power supply voltage at the measurement bench. The measured integrated field strength agrees with the expected value. Since the saturation is not so severe, the excitation curve obtained up to $I = 8.2$ A is extrapolated for use at higher current. The higher order multipole components were also measured and evaluated at $r = 42.08$ mm. The higher order components are summarized in Fig.6, and confirmed to be acceptable.

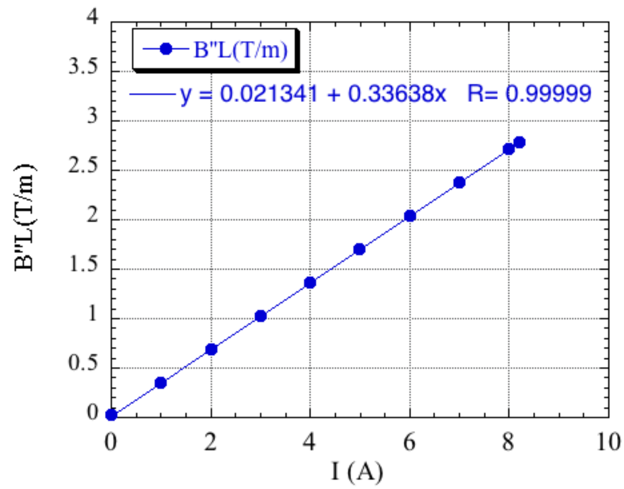

Figure 5: Integrated field $B''L$ (T/m) plotted against current I. No severe saturation is seen.

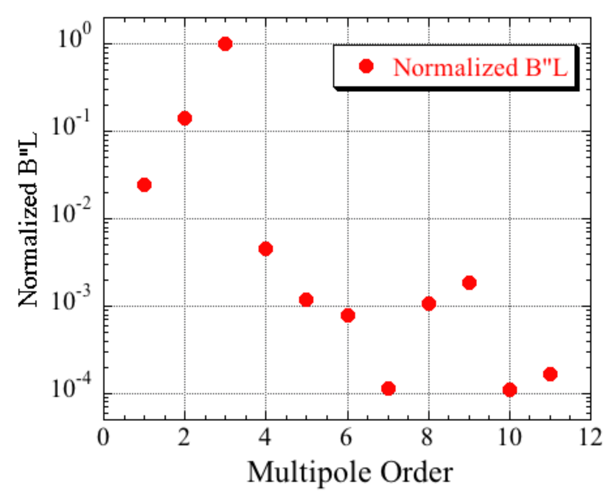

Figure 6: Normalized higher order multipole components at $I = 8.2$ A.

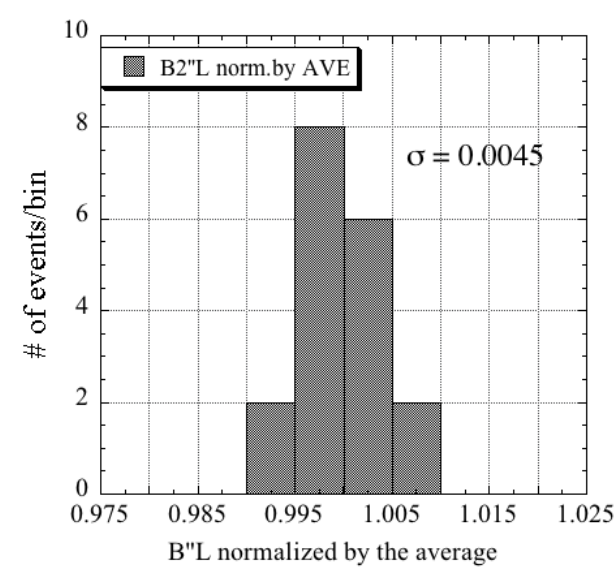

Figure 7: Normalized integrated strength by the average.

Figure 7 shows the distribution of the integrated sextupole field strength. Even though the width of the distribution is not too large, magnets of similar strength were paired, as two magnets are run by one power supply.

INSTALLATION

The installation and alignment of 28 magnets were completed in the end of March, just before the beam operation resumed. The magnets were installed in the locations indicated in Fig. 8. Blowers were installed near each magnet to take the heat away from the coil surface as much as possible during the operation. The temperatures of the coil are constantly monitored by the KEKB alarm system.

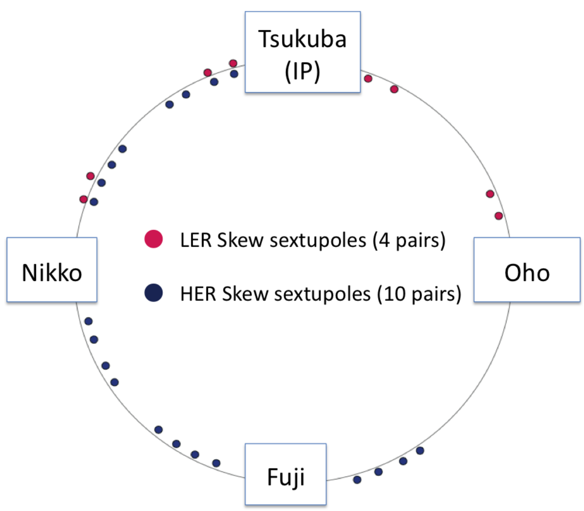

Figure 8: Location of the skew sextupole magnets in the tunnel. There are 20 and 8 magnets in the HER and LER, respectively.

LUMINOSITY BOOST

We began machine tuning using the skew sextupole magnets on May 2nd, 2009. The peak luminosity increased by about 10% within 24 hours of tuning. Figure 9 shows an example of luminosity tuning using skew sextupole magnets during the evening shift on May 2nd. The LER beam size at the IP shrank as the currents of the magnets went up, resulting in a luminosity enhancement. A beam study performed later showed an improvement of the X-Y coupling at the IP [3]. The peak luminosity eventually exceeded 21/nb/s on June 17th, 2009 as shown in Fig.10. Depending on how the machine is tuned, the magnets are sometimes operated at $I \sim 15$ A, which is a much higher current than was originally planned. At times, power supply current and voltage limits prevented us from reaching desired set points for luminosity tuning.

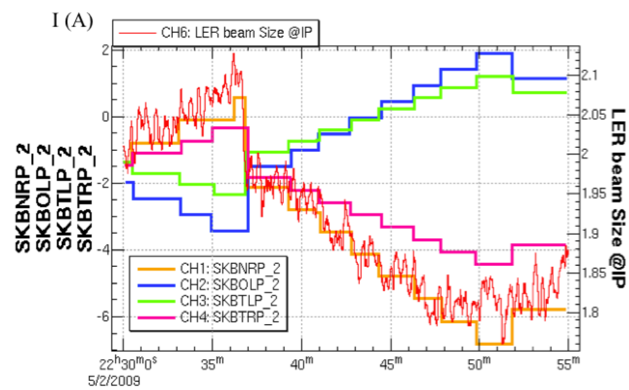

Figure 9: An example of machine tuning with sextupole magnets. The LER beam size at the IP, represented by the thinnest line, became smaller as the strength of the LER skew sextupole magnets changed.

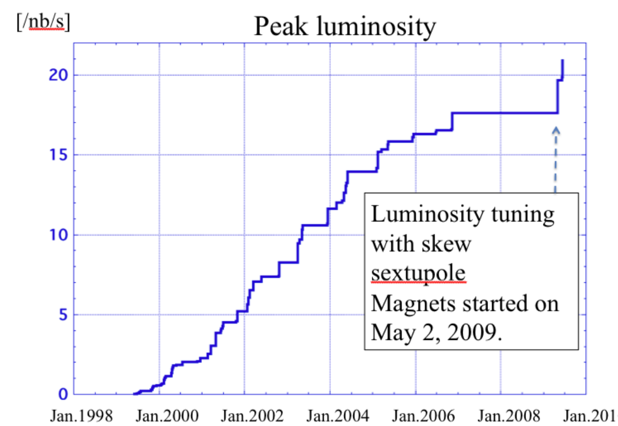

Figure 10: Peak luminosity trend since the KEKB commissioning. The peak luminosity went up significantly by the skew sextupole magnets.

SUMMARY

A new set of magnets, the skew sextupole magnets, were designed, manufactured and installed in the KEKB tunnel during the winter shutdown. The skew sextupole magnets were made on a low budget by maximizing the use of materials and equipment. The contribution of these low-budget skew sextupole magnets to the luminosity boost was significant.

REFERENCES

[1] D. Zhou, K. Ohmi, Y. Seimiya, Y. Ohnishi, and A. Morita, KEK Preprint 2009-10 (2009).

[2] Y. Seimiya and K. Ohmi, TH6PFP020, Particle Accelerator Conference PAC09, 4-8 May 2009, Vancouver, Canada.

[3] Y. Ohnishi et al. "Measurement of chromatic X-Y coupling", Phys. Rev. ST Accel. Beams **12**, 091002 (2009)