Monitoring of tensile force of PSC girder by measuring iron loss variation using EM sensors

Junkyeong Kim[1], Minsoo Park[2], Najeep Tareen[3], Byoung-Joon Yu[4], and Seunghee Park[5]

[1,2,3] *Department of Civil & Environmental Engineering, Sungkyunkwan University, Suwon, Gyonggi, 16419, Korea*
junk135@nate.com
pmsoo7@nate.com
Engr.najeeb12@gmail.com

[4] *Department of Convergence Engineering for Future City, Sungkyunkwan University, Suwon, Gyonggi, 16419, Korea*
Yubj1754@nate.com

[5] *School of Civil & Environmental Engineering, Sungkyunkwan University, Suwon, Gyonggi, 16419, Korea*
shparkpc@skku.edu

ABSTRACT

The actual tensile force of pre-stressed (PS) tendons of a pre-stressed concrete (PSC) girder is one of the important factors for evaluating the performance of PSC girder bridges. To measure the tensile force of the PS tendon, this study proposed an iron loss variation based tensile force estimation method using embedded EM sensors. The iron loss of PS tendons are changed according to the applied tensile force. To measure the iron loss of PS tendon of PSC girder, the EM sensor should be embedded in the PSC girder because the PS tendons were located in inside of PSC girder. To verify the proposed method, the experimental tests were performed. The EM sensors were embedded into PSC girder specimen and the iron loss changes due to the variations of tensile forces were measured using EM sensors. According to the measurement results, the proposed method can be a one of the solution to monitor the tensile force of PS tendons.

1. INTRODUCTION

The PSC bridges have been constructed world widely after the first PSC bride was built in 1936. The tensile forces of prestressing tendons are most important factor to maintain the PSC bridges. However, the tensile force of the PS tendon can changed due to many kinds factors including instantaneous losses such as elastic shortening, friction, and anchorage set occurring at the time of transfer of the prestressing force, as well as time dependent losses due to steel relaxation and concrete creep and shrinkage that occur after transferring and during the life of the member. To measure the tensile force of PS tendons, a variety of studies have been researched using fiber optic sensors (Kim et al., 2012) and magnetic sensors (Wang et al., 2005). This research concentrated to find the relation between the iron loss and tensile force and the way to monitor the tensile force of PS tendons using the iron loss measured by the EM (Elasto-Magnetic) sensors.

2. TENSILE FORCE ESTIMATION USING IRON LOSS

The iron loss it consists of hysteresis loss and eddy current loss, both depend upon magnetic properties of the materials used to construct the core of transformer and its design. So these losses in transformer are fixed and do not depend upon the load current. So core losses in transformer which is alternatively known as iron loss in transformer can be considered as constant for all range of load. Hysteresis loss in transformer is denoted as,

$$W_h = \mathrm{K}_h \mathrm{f}(\mathrm{B}_m)^{1.6} \text{ watts} \quad (1)$$

Eddy current loss in transformer is denoted as,

$$W_e = \mathrm{K}_e \mathrm{f}^2 K_f^2 \mathrm{B}_m^2 \text{ watts} \quad (2)$$

where, K_h = Hysteresis constant. K_e = Eddy current constant. K_f = form constant. Copper loss can simply be denoted as,

$$\mathrm{I}_L^2 R_{2\prime} + \text{Stray loss} \quad (3)$$

where, I_L is load of transformer, and $R_{2'}$ is the resistance of transformer referred to secondary.

The iron loss is affected by the induced stress to the specimen. Thus the tensile force of PS tendons could be monitored by measuring iron loss variation using EM sensors.

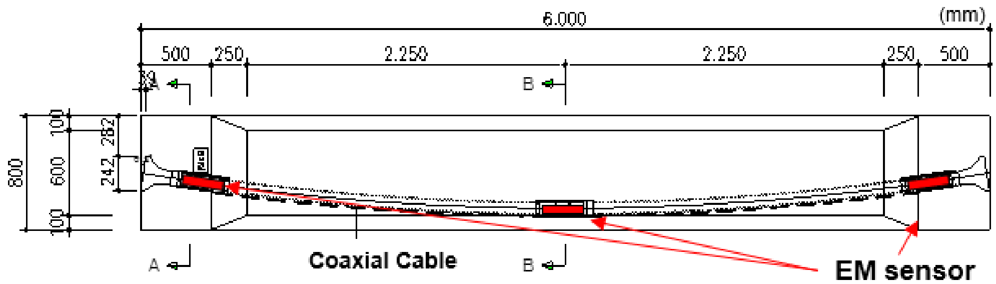


Figure 1. Geometric scheme of test specimen

3. EXPERIMENTAL STUDY

3.1. Test setup

To verify the proposed method, the experimental study was performed using don-scaled girder model as shown in Figure 1. The EM sensor was embedded into the down-scaled girder as shown in figure 2 and measured the iron loss change according to the tensile forces.

(a) Anchorage part

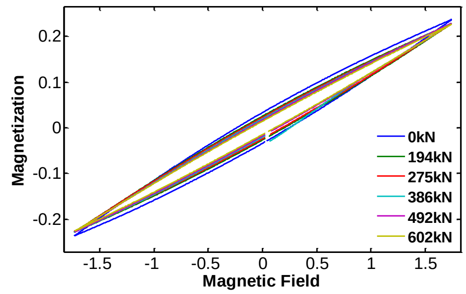
(b) Maximum eccentric part

Figure 2. Installation of EM sensors

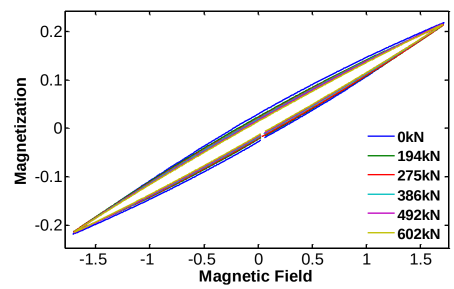
The tensile force was induced 0, 194, 275, 386, 492 and 602 kN using hydraulic jacking device. The B-H curve was measured every tensile force step.

3.2. Measurement result

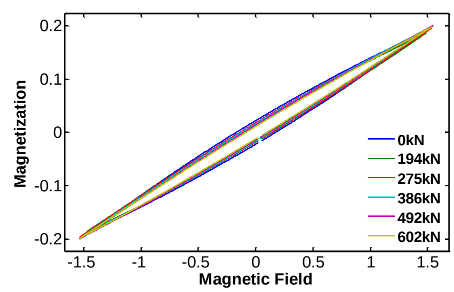
Figure 3 shows the measurement B-H curve at the tensile force step. The area of B-H loop that means the iron loss was decreased due to increase of tensile force.



(a) Left anchorage part



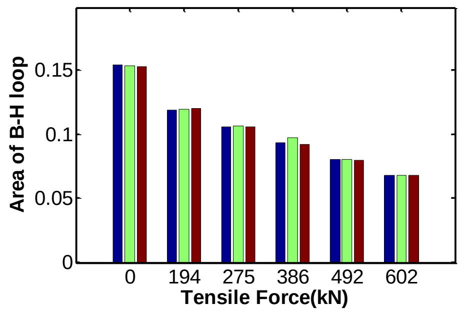
(b) Maximum eccentric part



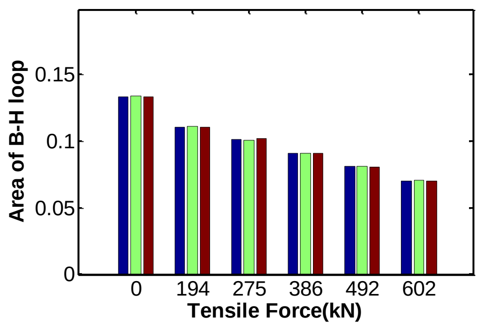
(c) Right anchorage part

Figure 3. B-H loop variation

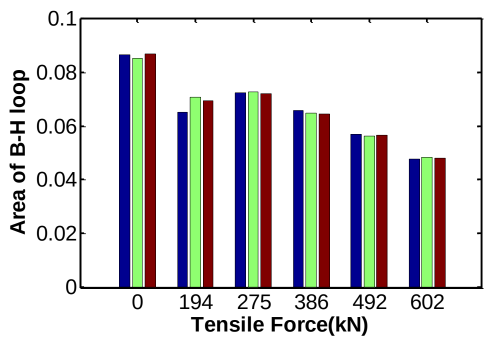
To quantify the changes in iron loss, the area of B-H loop was extracted from measured B-H curve. Figure 4 shows the area variations according to the tensile forces.



(a) Left anchorage part



(b) Maximum eccentric part



(c) Right anchorage part

Figure 4. Area of B-H curve variation

The area of B-H curve was decreased according to the tensile force increase. Thus the tensile force of PS tendons could be monitored by tracking the iron loss variation measured by EM sensors.

4. CONCLUSION

This research proposed the tensile force monitoring method using EM sensor. The iron loss of PS tendon is changed by the induced tensile force, thus these could be monitored using EM sensor. To verity proposed method, the experimental study was performed using down-scaled PSC girder model. The EM sensor was installed left and right anchorage part and maximum eccentric part. The tensile force was induced step by step and the B-H curve was measured at each tensile force step. The area of B-H curve, that represent the iron loss, was decreased according to increase of tensile force. Thus the tensile force of PS tendons could be monitored by tracking the iron loss variation using EM sensors.

ACKNOWLEDGEMENT

This work is financially supported by Korea Ministry of Land, Infrastructure and Transport(MOLIT) as「U-City Master and Doctor Course Grant Program」.

REFERENCES

Kim, J. M., Kim, H. W., Park, Y. H., Yang, I.H. and Kim, Y.S., (2012). FBG sensors encapsulated into 7-wire steel strand for tension monitoring of a prestressing tendon. *Advanced Structural Engineering*, vol. 15, pp. 907-917.

Wang, M. L., Wang, G. and Zhao, A. (2005). Application of EM stress sensors in large steel cables. *Sensing Issues in Civil Structural Health Monitoring*, Springer, London: Springer. Pp. 145-154.