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BEAM STABILITY OF THE TAIWAN LIGHT SOURCE STORAGE RING

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Abstract

The Taiwan Light Source Storage Ring (SR) has been in operation since many years ago. Maintaining best stability of the electron beam is becoming the main challenge. This study endeavored to improve the electron beam stability and injection efficiency of The Taiwan Light Source Storage Ring (SR). Employing the artificial neural network (ANN)-constructed experiment design to analyze and optimize the storage ring betatron tunes .This report outlines the details of the beam stability and injection efficiency process experiment.

INTRODUCTION

Using the basic theory of response surface methodology (RSM), this study aimed to improve the electron beam stability and injection efficiency of the National Synchrotron Radiation Research Center (NSRRC) storage ring. Artificial neural network (ANN) design software, known as computer-aided formula engineering (CAFE) [1], was used to analyze and optimize the betatron tunes of the storage ring. We aimed to identify the main influential the betatron tunes of the storage ring and, through optimization, develop the betatron tunes of the storage ring adjustment program that best stability and maximizes injection efficiency of the electron beam.

DATA ANALYSIS

Artificial Neural Network

ANNs are construction methods for nonlinear models. Among which, back-propagation networks (BPNs) are currently the most representative and commonly applied of the ANN learning models [2, 3].

Beam Stability Analysis

After calculating the ANN model construction, we obtained the "train- and -test" error convergence curve, as shown in Fig. 1. The representative model construction was ideal because they appear to converge after approximately 1,500 computations.

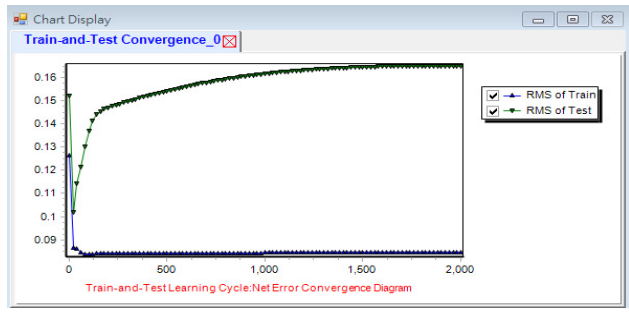

Figure 1: The "train- and -test " error convergence curve.

The "train- and -test" scatter plots for the training sample is shown in Fig. 2 respectively. The predictive ability of the representative model was also ideal [4].

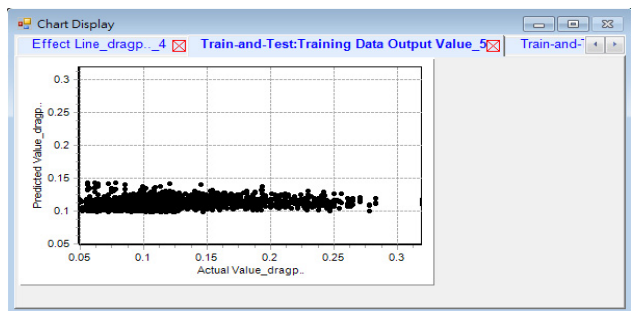

Figure 2: The "train- and -test " scatter plot of the training samples.

Analysis of the experimental results included sensitivity analysis and influence line analysis. Sensitivity analysis was conducted using weight value analysis graphs, and influence line analysis was conducted using a main effect diagram with status. The sensitivity analysis results revealed the significance of quality factors, as shown in Fig. 3. We found the betatron tune fy quality factor had the highest significance.

- The weight of the betatron tune fx was 0.015.
- The weight of the betatron tune fy was 0.061.

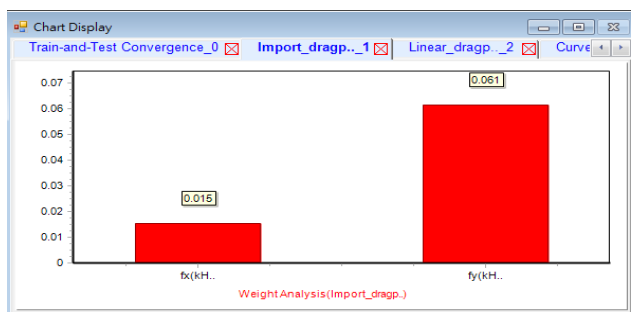

Figure 3: A bar graph of Y significance.

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Analysis of the results clearly showed the curved figure and significance of the quality factors, as shown in Fig. 4.

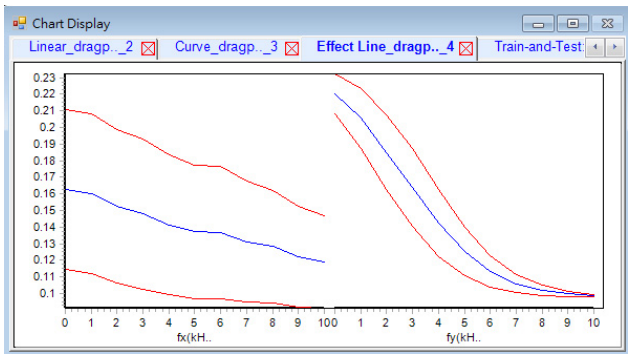

Figure 4: Status effect diagram.

The ANN-optimized parameter solution is shown it. The storage ring electron beam stability was estimated as 0.1029%.The betatron tune fx was 758.93kHz,fy was 441.53kHz.

Injection Efficiency Analysis

After calculating the ANN model construction, we obtained the "train- and -test" error convergence curve, as shown in Fig. 5. The representative model construction was ideal because they appear to converge after approximately 250 computations.

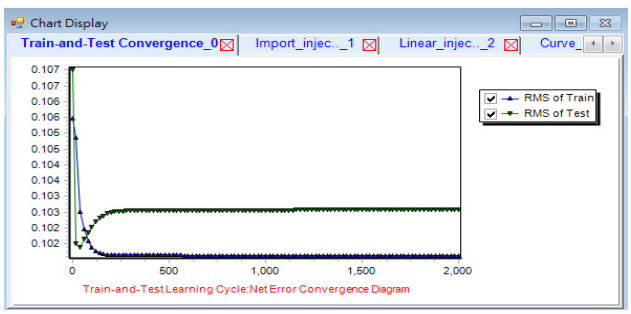

Figure 5: The "train- and -test" error convergence curve.

The "train- and -test" scatter plots for the training sample is shown in Fig. 6.

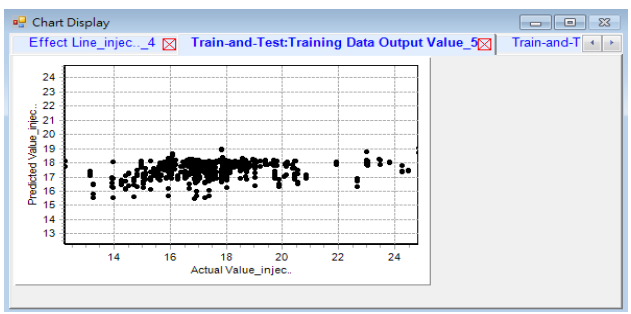

Figure 6: The "train- and -test" scatter plot of the training samples.

Analysis of the experimental results included sensitivity analysis and influence line analysis. Sensitivity analysis was conducted using weight value analysis graphs, and influence line analysis was conducted using a main effect diagram with status. The sensitivity analysis results revealed the significance of quality factors, as shown in Fig. 7. We found the betatron tunes fx and fy quality factor had the highest significance.

- The weight of the betatron tune fx was 0.043.
- The weight of the betatron tune fy was 0.034.

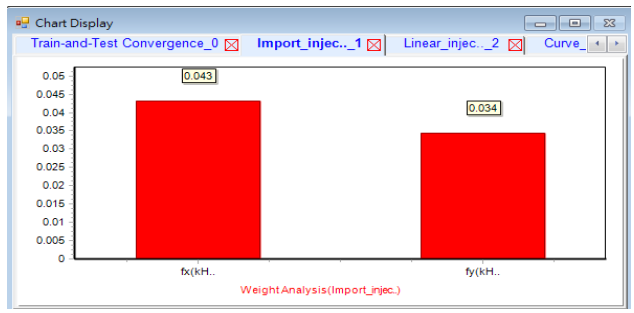

Figure 7: A bar graph of Y significance.

Analysis of the results clearly showed the curved figure and significance of the quality factors as shown in Fig. 8.

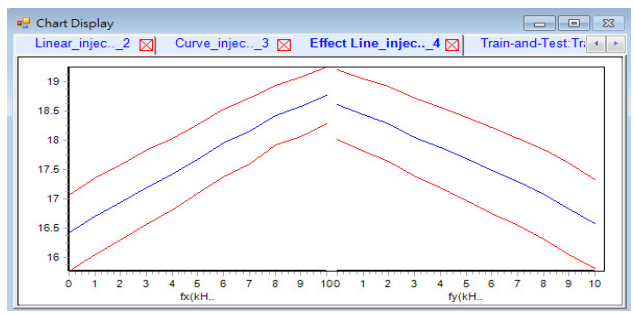

Figure 8: Status effect diagram.

The ANN-optimized parameter solution is shown it. The storage ring electron beam injection efficiency was estimated as 19.54%. The betatron tune fx was 766.89kHz, fy was 439.06kHz.

Beam Stability and Injection Efficiency Analysis

After calculating the ANN model construction, we obtained the "train- and -test" error convergence curve, as shown in Fig. 9. The representative model construction was ideal because they appear to converge after approximately 100 computations.

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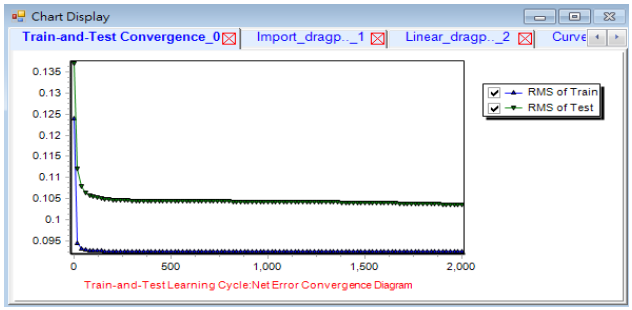

Figure 9: The "train- and -test" error convergence curve.

The "train- and -test" scatter plots for the training samples are shown in Figs. 10, 11.

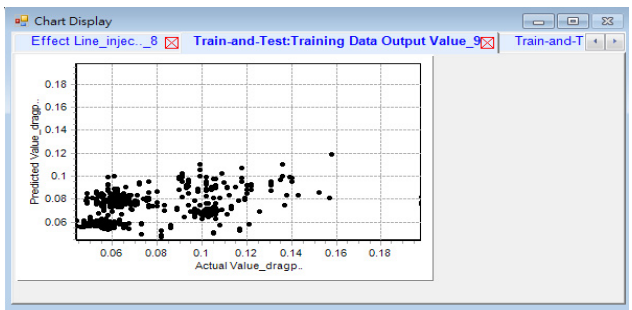

Figure 10: The "train- and -test" scatter plot of the training samples.

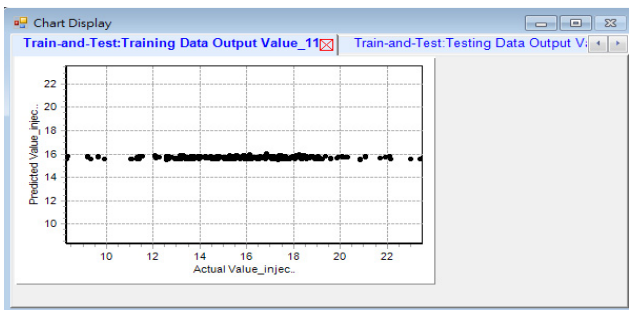

Figure 11: The "train- and -test" scatter plot of the training samples.

Analysis of the experimental results included sensitivity analysis and influence line analysis. Sensitivity analysis was conducted using weight value analysis graphs, and influence line analysis was conducted using a main effect diagram with status. The sensitivity analysis results revealed the significance of quality factors, as shown in Figs. 12, 13. We found the betatron tunes fx quality factor had the highest significance.

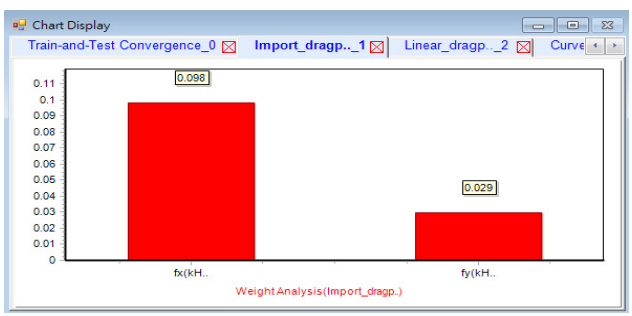

Figure 12: A bar graph of Y significance.

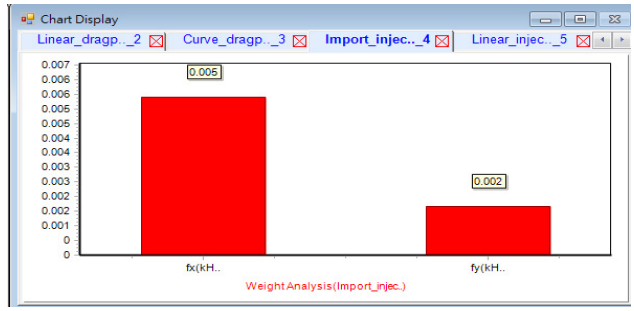

Figure 13: A bar graph of Y significance.

The ANN-optimized parameter solution is shown it. The storage ring electron beam stability was estimated as 0.0428% and injection efficiency was estimated as 15.4420%. The betatron tune fx was 753.48kHz, fy was 437.05kHz.

CONCLUSIONS

This study endeavored to analysis the best stability and injection efficiency of a storage ring electron beam at the NSRRC. Using BPN for analysis and the train- and -test experiment method to effectively estimate the generalization error. Analysis of the experimental results The storage ring electron beam stability was estimated as 0.1029%. The betatron tune fx was 758.93kHz, fy was 441.53kHz. The storage ring electron beam injection efficiency was estimated as 19.54%. The betatron tune fx was 766.89kHz, fy was 439.06kHz. The storage ring electron beam stability was estimated as 0.0428% and injection efficiency was estimated as 15.4420%. The betatron tune fx was 753.48kHz, fy was 437.05kHz. These results demonstrate the significant benefits of using ANN parameter optimization theory hoping to enhance accelerator operation quality.

REFERENCES

[1] Yeh, I-Cheng, 2009, "Advanced Design of Experiments", Wu-Nan Book Inc., Taiwan.
[2] Arti Gokhale, et. al., "Artificial Neural Network Calculates Backward Wave Oscillator Parameters Reliably for Pulsed Accelerators", APAC 2007, RRCAT, India.
[3] D. Schirmer, et al., "Electron Transport Line Optimization Using Neural Networks and Genetic Algorithms", Proceedings of EPAC 2006, Edinburgh, Scotland.
[4] Hung-Chiao Chen et. al., "Optimization of the Electron Beam Extraction Efficiency in a Booster for TLS", IPAC 2012, New Orleans, USA.