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Esneyerek Kilitlenen Bağlantı ElemanlarındaTutma/Çözme Kuvvetinin Malzeme Cinsi ve Sürtünme Katsayısına Göre Yapay Sinir Ağları Metodu ile Modellenmesi

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MAKALE BİLGİSİ

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***Anahtar Kelimeler**:*
I Tipi Esneyerek Kilitlenen Bağlantı Elemanları, Plastik Malzemelerin Tasarımı, Yapay Sinir Ağı Modellemesi (YSA)

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ÖZET

Bu çalışma da esneyerek kilitlenen bağlantı elemanlarının (Snap-Fits) tutma/çözme kuvvetlerinin hesaplanması için bir Yapay Sinir Ağı Modeli geliştirilmiştir. Bu hesaplamanın bilgisayar destekli tasarım metodolojisi kullanılarak tutma/çözme kuvvetinin belirlenmesi için, tırnaklı birleştirme bağlantı tasarım modelinin uç açısı (α) ve malzeme cinslerinin sürtünme katsayıları referans alınmıştır. Bu amaç ile malzeme cinsi ve tırnaklı bağlantının uç açısı verilerek herhangi bir mühendislik hesabına gerek kalmaksızın, bilgisayar destekli sonuç hesap edebilen bir Yapay Sinir Ağı (YSA) modeli geliştirilmiştir. Elde edilen modelin MEP % = 0.624073, RMSE= 0.008977 ve R^2= 0.99999 olarak bulunmuştur. Böylece hem güvenilir hem de hızlı bir yöntem ile malzeme cinsi ve tırnak kilitleme ucunun açısal değerlerine göre sonuç üretebilen bir tasarım modeli geliştirilmiştir.

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Modeling of Mating / Seperating Force in Snap-Fit Joints by Artificial Neural Networks Method by Material Type and Friction Coefficient

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ABSTRACT

In this study, an Artificial Neural Network Model has been developed to calculate the mating / separating forces of Snap-Fit joints. In order to determine the mating / separating force of this calculation using Computer Aided Design methodology, the tip angle (α) and friction coefficients of material types are taken as reference. For this purpose, an Artificial Neural Network (ANN) model has been developed. In this way, the material type and the end angle of the claw connection is given, without the need for any engineering account, a software capable of calculating computer-aided results has been developed. MEP% = 0.624073, RMSE = 0.008977 and R^2 = 0.99999. With such a reliable and fast method, a Design method has been developed which can produce results according to the material type and the angular values of the connection snap-fit type.

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1. INTRODUCTION *(GİRİŞ)*

With the improvement of the technical features brought to the developing technology and materials, plastic materials have become the raw material of many sectors. The increase in the demand for plastics materials and the connection with other materials has gained importance. One of the plastic fasteners, snap-fits has been the subject of many researches due to their design, easy assembly and disassembly features, and environmental friendly features. One of the most common plastic mounting methods is the joints obtained by using the snap-fits joints. These connections are more advantageous than conventional fasteners due to their features such as cost, time, ease of installation and reproducibility. These connections enable the full use of the mechanical properties of the material, creating a more convenient product range. Plastic-plastic, metal-metal or metal-plastic can be obtained in three different ways. Due to the advantage of the stretching properties, the connection types formed by the plastic material are more common. Bonenberger Paul R. has prepared a handbook for the snap-fits. In his work classified the snap-fits joint element. He worked on design parameters and analyzed the snap-fits types. Provides detailed information about developing design problems and what can be done for solution [1]. The use of the snap-fits is based on an accurate calculation of the interface and the associated mating force. The pairing force is proportional to the intermediate intersection point. The plastic part is the intermediate intersection point ratio which is very sensitive to the dimensional error. Inadequate interference can result in loose assembly, while overheating can damage the thin-walled plastic parts by preventing assembly. The possibility of unqualified interference causes damage in high quality applications such as cars and electronics. Chen and Lan have provided a stable strong locking mechanism in order to reduce the need for a sensitive breakpoint and improve the installation stability. It has made a design formulation to find configurations of the mechanism that produces the most constant matching. The resulting pictorial simulations and experiments showed that the constant force fit was less than the typical locking mechanism [2]. Kulkarni et al. used RADIOSS, HyperCrash and other HyperWorks tools. A typical plastic flexing system has shown a systematic approach to manufacturing and service ease for the snap-fits design. From the study, it was concluded that the areas of high stress concentration were sensitive to the disassembly angle, element thickness and sharp corners of the snap-fits. Such problem areas are developed by notches at appropriate angles in the mating and base sections, respectively. Design changes should be made according to the criteria of manufacturing and service ease. If the design repeats more than 4 times to meet the objectives, it is recommended that the interlocking design be cross-checked for both push and pull more often preferred [3]. A typical locking assembly simulation includes three critical stages, namely stretch, capture and retention. McMaster W., and Lee C., S., have disclosed that typical stretching conditions of a typical cantilever beam design are not appropriate but that alternative designs must be made against a desired material. With designed "U düzey and eri L ger shaped connection designs, it makes the applied stresses acceptable by using desired material. Both formulas have derived formulas and have confirmed these formulas with finite element analysis. With the work done, more deviations were obtained with less cost without causing high voltages [4]. Annis has developed a nonlinear deformation analysis method for the most commonly used I type cantilever beam design. With this study, the cantilever beam assembly-disassembly angle, the material used, the friction coefficient, cantilever beam connection shape based on the reliability of the quotation has been optimized. He studied the mechanical properties of the cantilever snap-fits connection in detail [5].

The variety and possible combinations of the snap-fits, the dimensions on the parts and the positioning make it possible to have unlimited design possibilities. Messler R.W. et al. explained beam types in a study of seven series. In his works he gave a general description of the fasteners and he schematized the plug-in connections required for real optimization. It also carried out a hierarchical classification of the assembly parts. In its series, the placement of an integrated plug-in connector, rather than the traditionally made and focused individual case, has been classified as locking, locator and reinforcement to eliminate features such as vibration and rotation. The appropriate optimal locking pair offered a systematic approach to selection. He tried to show the usefulness of the methodology with a real case study. He then presented a systematic procedure to formalize the production of alternative concepts for a particular design of the fasteners. All relevant design areas where the procedure and the alternatives are available are provided with alternative connection interface geometries, assembly procedures, additional features and restriction options (for special applications). The procedure is easy to use, effective and efficient as well as offers a number of alternative results but is not large enough to prevent the choice of optimization used. In addition, he designed designs using additional concepts and considered them as a secondary way of evaluating the design problem with multiple objectives. Finally, using a systematic product design, it has carried out a snap-fits connection-specific assembly. The design, designed for installation in the first six stages of the design, is intended to lead the reader to be used in situations where practical design is required by exemplifying the improved methodology with a case study [6-12].

Developing environmental requirements direct the researchers to make improvements in the snap-fitsconnections during the disassembly period. In this context, L. Hua et al., Work in CRG: Industry LLC. The effect of the shape memory polymer (vertex) based transition elements produced by the components on the duration of disassembly and re-use. A total of six different insert sets were tested ten times for removal time. The stress caused by the training process was simulated and analyzed. One of the designs showed the shortest mean disassembly time, the lowest standard deviation and the lowest stress. However, the general reuse of plug-in parts is not sufficient for industrial application [13]. In order to simplify the disassembly process, Carrell J. et al. designed and activated the activated shape memory polymer snap-fits element when exposed to heat. The product designed for release with a release angle was tested for demonstration of active release. Pluggable and active disassembly process parameters were analyzed. The active disassembly process affects both the heating method and the temperature. Increasing the temperature change shortened the disconnection time of the connection. The best result was 150 ° C in terms of disassembly time and signal noise ratio. The test results showed the benefits of the existing active disassembly element with shape memory and the likelihood of an acceptable heat dissolving connection element for more efficient disassembly [14]. He and his friends have tried to improve the features of the locking connections using intelligent material. The ABS material has formed a connection design consisting of a beam-type shell and a shape-memory actuator positioned in the shell. The finite element model of this design has been formed and the von-mises stresses for the actuator, the deviation for the beam shell and other design parameters, especially the analysis of the matching forces, were investigated. By optimizing the relationship between the height of the beam type shell and the width of the shell to match and maximum deviation, the study proved to be validated and usable [15]. The Artificial Neural Networks method can be successfully applied in many engineering fields [16].

In this study, the assembly and disassembly forces of the eleman I type (cantilever beam) snap-fits, which are one of the snap-fits, have been investigated. For this purpose, a modeling was made with reference to the inclination angle and material friction coefficients for an I type built-in beam type connection. Depending on the material and connection design features, previously obtained models were analyzed and an Artificial Neural Network (ANN) model was created in accordance with the data of these models. It is determined that the results of experimental data are compatible with the newly developed model.

2. MATERIAL AND METHOD *(MATERYAL VE METOT)*

Snap-Fits are usually made of plastic materials. These parts are generally used as connecting elements. The most common features of these assemblies are the ability to perform the connection manually and to be easily removed without any tools. For this purpose, they are designed, dimensioned and produced in accordance with the designs of the places where the relevant connection can be realized in different types and models. The purpose is that the connection can be easily carried out or the connection can be removed.

The design process of these joining elements, which are widely used in the very simple machine, automotive and transportation vehicles we use in daily life, consists of important steps. In order to realize the design, defining the engineering approach of the event has an important place. The assembly and disassembly force varies depending on the design of the retaining parts of the tab assemblies and the pair of materials. Below are the different types of beam connection models (Figure 1).

Generally, the end structures of the snap-fits are produced in the form of an cantilever beam. Depending on the inclination angle and material relationship of this form, the bonding and disengaging force varies. The general engineering model of the form is given in Figure 2. Small tilt angles (α) reduce the mounting force. In contrast, small angles of inclination (α) make the disassembly process difficult or impossible. For this reason, very pointed designs are not recommended. The main goal of the design is the robustness of the connection and the ability to perform its functions in the place of the task. The rigidity of the connecting element (k) is defined by the ability of the connection to perform its function in integrity. The stiffness is achieved either by the material having a greater ratio of elasticity (E) or by increasing the moment of inertia (I). By multiplying these two parameters with each other (E: I), the total stiffness value is obtained. The friction coefficient, which may occur in contact with the plastic materials of the same type, is determined in the literature in different ratios from the normal friction coefficients (Table 1).

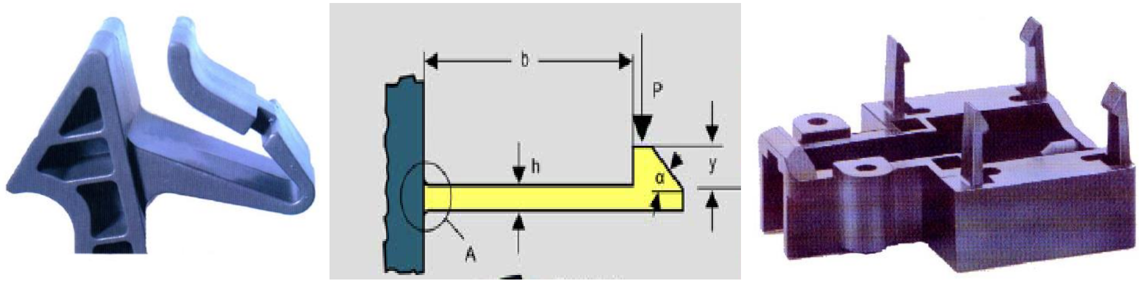

Figure 1. Threaded connection end designs *(Tırnaklı bağlantı uç tasarımları)*

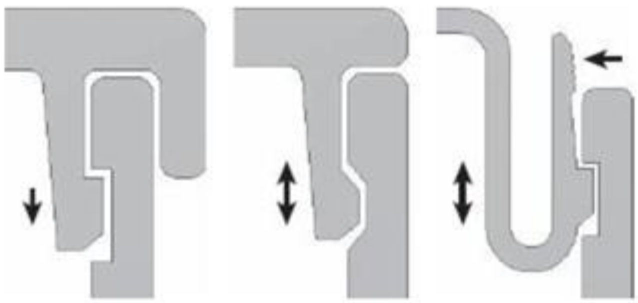

Figure 2. Types of joints of the cantilever beam *(Tırnaklı bağlantıların tırnakların birleşme tipleri)*

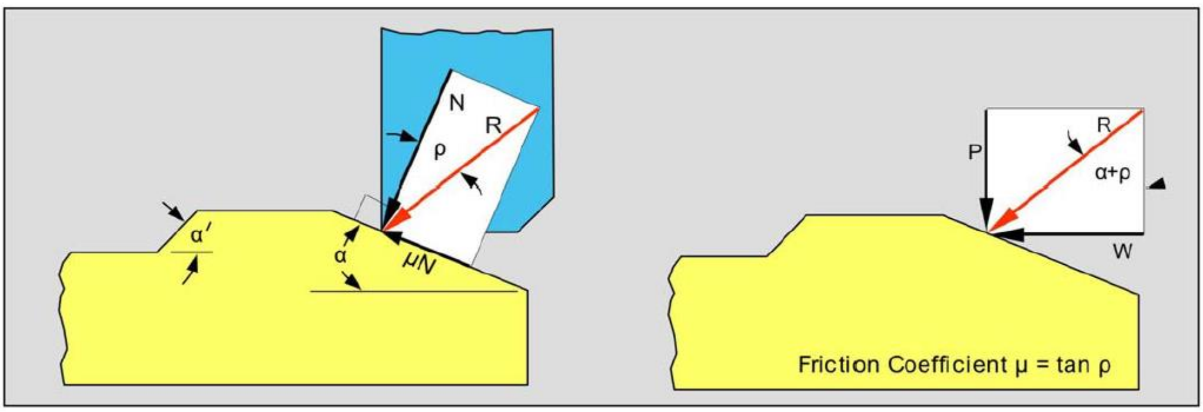

Figure 3. Defining the engineering force of assembly /disassembly *(Tutma/Çözme kuvvetinin mühendislik olarak tanımlanması)*

In case of assembly;

$$W = P.tan(\alpha + \rho) = P.(\frac{\mu + tan\alpha}{1 - \mu.tan\alpha})$$

In case of disassembly;

$$W = P.tan(\alpha - \rho) = P.(\frac{\mu' + tan\alpha}{1 - \mu'.tan\alpha})$$

Table 1. Friction coefficients for plastic materials (for steel materials) *(Plastik malzemeler için sürtünme katsayıları (Çelik cinsi malzemelere karşı))*

	Material												
	PTFE	**PE rigid (x2.0)**	**PP (x1.5)**	**POM (x1.5)**	**PA (x1.5)**	**PBT**	**PS (x1.2)**	**SAN**	**PC (x .2)**	**PMMA (x1.2)**	**ABS (x1.2)**	**PE flexible (x1.2)**	**PVC (x1.0)**
Friction Coefficient	0.12-0.22	0.20-0.25	0.25-0.30	0.20-0.35	0.30-0.40	0.35-0.40	0.40-0.50	0.45-0.55	0.45-0.55	0.50-0.60	0.50-0.65	0.55-0.60	0.55-0.60

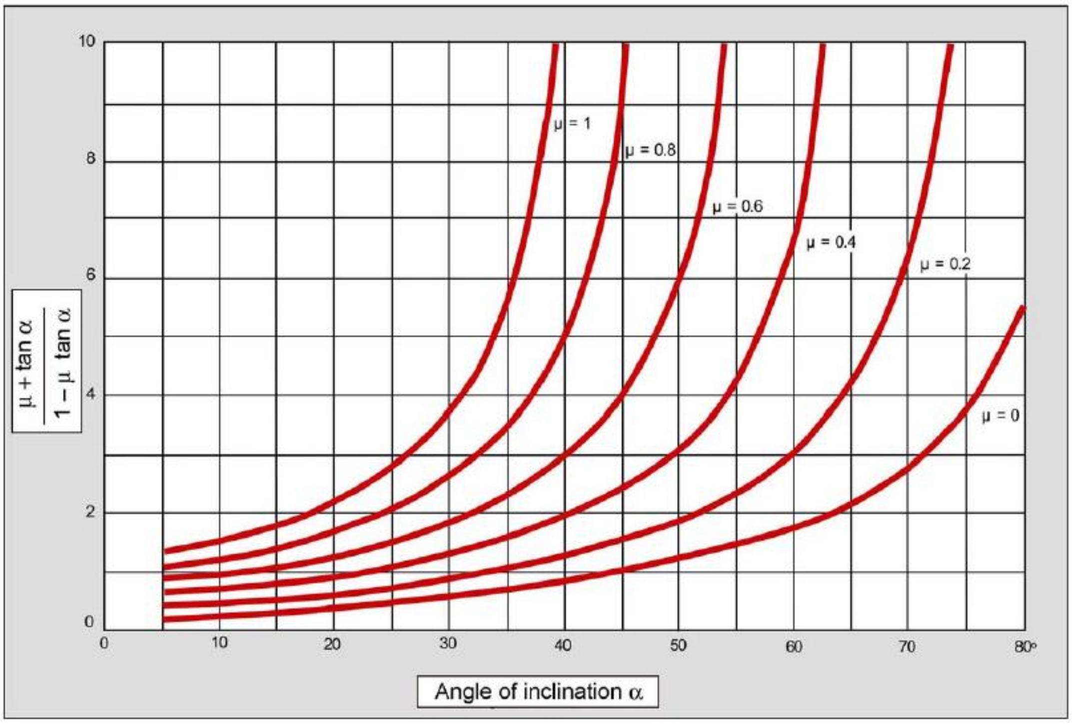

Figure 4. Friction coefficient and friction angle relation of the friction coefficient depending on the tip angle and friction coefficient *(Esneyerek kilitlenen bağlantılarda uç açısı ve sürtünme katsayısına bağlı olarak sürtünme katsayısı ve sürtünmeaçısı ilişkisi)*

3. MODELING and ANALYSIS *(MODELLEME VE ANALİZ)*

Artificial Neural Networks (ANN), a branch of artificial intelligence; It is a method that can give successful results by applying the same human brain's learning and reasoning methods to the problems by imitating the functions of the human brain. The advantage of this method is its ability to make predictions depending on the learning algorithm. Firstly, the model learns the output values against the inputs of a problem and reflects the changes in the input values to the result. Another feature of the learning process is not limited to the first learning. Model; when an input is already given, it is to update the database by transferring the predicted results into learning algorithm and not to terminate the learning function after the first learning action. It shows a live system feature with this feature.

Although there are many commercial software in general; Artificial Neural Network (ANN) models can be created by writing codes in Matlab, C ++, Java languages. There are mathematical expressions defined with functions in the back of these codes. In the main algorithm of Artificial Neural Network; there is a system of inputs, hidden layers and results. In this system, there is a process of iterations that corresponds to the main target inputs until the output results are close to the actual values.

Artificial Neural Networks models have many different learning methods and different functions. As learning functions; including trainb, trainbfg, trainbfgc trainbr, trainbuwb, trainc, trainlm etc. In this study, Trainlm (Levenberg-Marquardt) backpropagation learning model was used. The hidden layers have many different functions. These functions; Hyper transfer transfer function, hard transfer transfer function, hardlim transfer transfer function, hardlim transfer transfer function, logins transfer function, logins transfer function, transfer function function, satlin Saturating linear transfer function, satlins Symmetric saturating linear transfer function, softmax Softmax transfer function, tribas Triangular basis transfer function. In this study, block functions with the highest regression values of the best learning, test and estimation values are used.

4. RESULT AND DISCUSSION *(SONUÇLAR VE TARTIŞMA)*

In order to determine the disassembly and assembly force of the snap-fits joints, firstly, the numerical value of the graphs obtained from the experimental data was obtained according to each curve. These values are classified according to the values of the parameters and are classified in an Excel file. Then, in Matlab software, a code was prepared in ANN Toolbox and different algorithms and performances were evaluated according to the code prepared.Figure 5 shows an ANN model. In this model, 2 inputs + 7 tansig + 17 logsig + 1 purelin + 1 output model is used. In Figure 6, it is seen that ANN model which is developed for determining the removal and dissociation forces of claw connections has achieved the best learning performance and this value. The best convergence value of 8.0594 E-5 seems to be close to the real result.

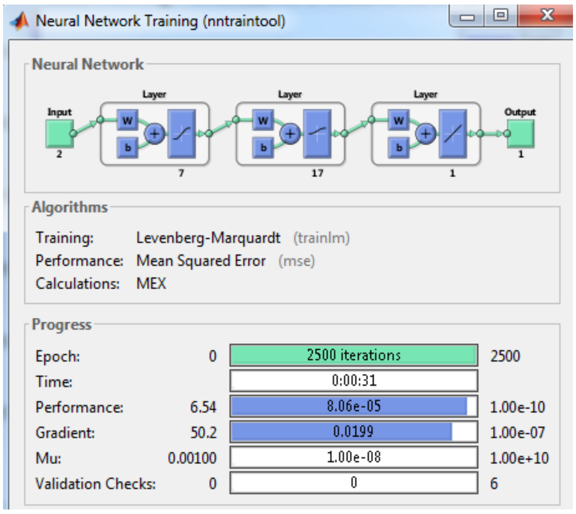

Figure 5. ANN model developed to determine the assembly and disassembly forces of the snap-fits *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modeli)*

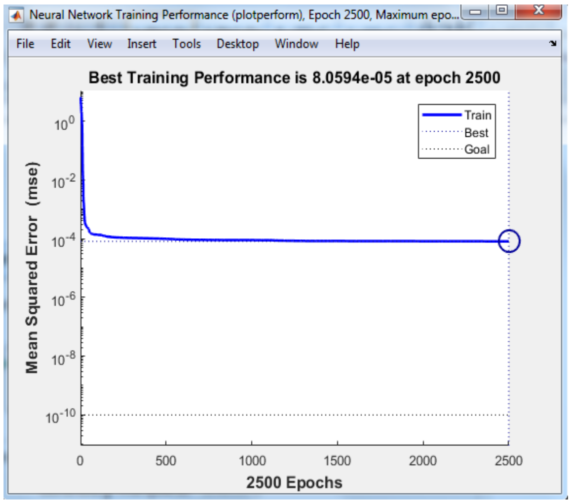

Figure 6. Optimal performance of ANN model developed for determine the assembly and disassembly forces of the snap-fits *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin en iyi performansı)*

Figure 7 shows the regression of the learning function of ANN model, which was developed to determine the disassembly and assembly forces of the snap-fits. Figure 8 the best estimation performance of the SSA model developed to determine the demount and release forces of the snap-fits is seen. It is seen that the learning function according to the figure performs these functions with an error of less than 10^{-9}, and the ability to test and estimate with an error of less than 10^{-5}. It is seen that the best proposed model is reached in the program.

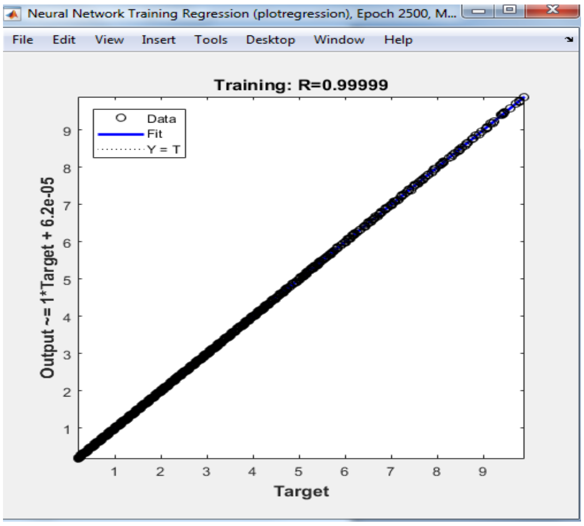

Figure 7. Learning function regression value of ANN model developed for determine the assembly and disassembly forces of the snap-fits *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin Öğrenme fonksiyonunu regresyonu değeri)*

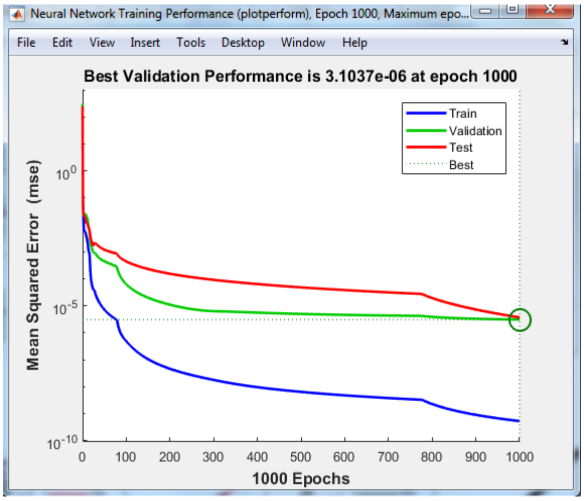

Figure 8. Best predicted performance of ANN model developed for determine the assembly and disassembly forces of the snap-fits *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin en iyi tahmin performansı)*

Figure 9 is a 30 bins Error Histogram chart of the ANN model developed for the determination of the assembly and disassembly forces of the snap-fits and a 20 bins Error Histogram graph of the ANN model developed to determine of the assembly and disassembly forces of the snap-fits. The 30 bins graph shows that the test and prediction values reached to the zero error value, and that there are acceptable deviations for the few inputs. According to the 20 bins graph in Figure 10, it is determined that the data value of approximately 98% yields a% zero error value.

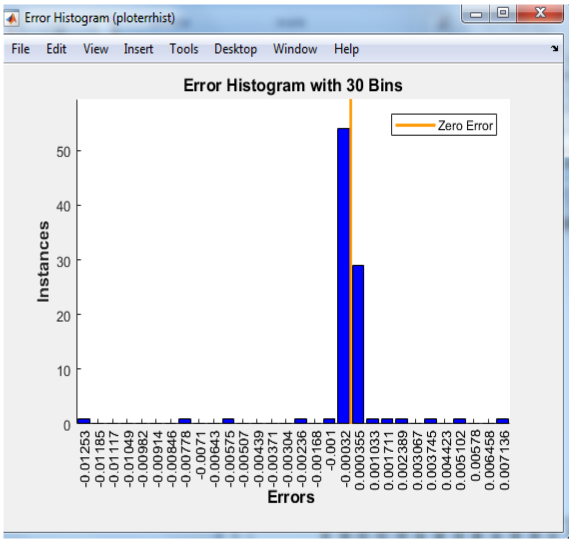

Figure 9. A 30 Bins Error Histogram graph of the ANN model *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin 30 Bins lik Error Histogram grafiği)*

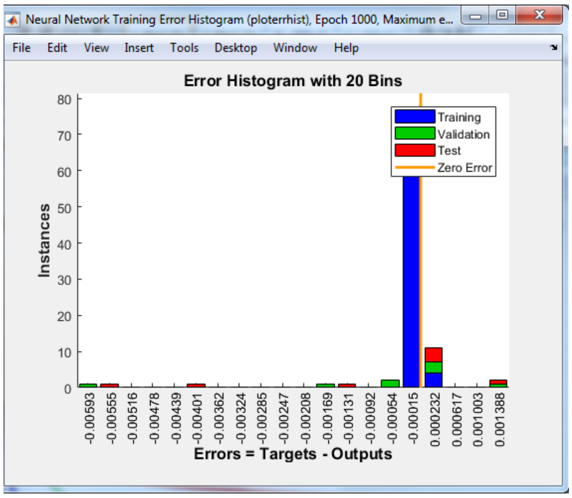

Figure 10. A 20 Bins Error Histogram graph of the ANN model *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin 20 Bins lik Error Histogram grafiği)*

Figure 11 shows the Training, Test, Validation and Overal performance values of the ANN model developed to determine the assembly and disassembly forces of the snap-fits. Learning, Test, Estimation and general performance values are very close to 1 (0.9999).

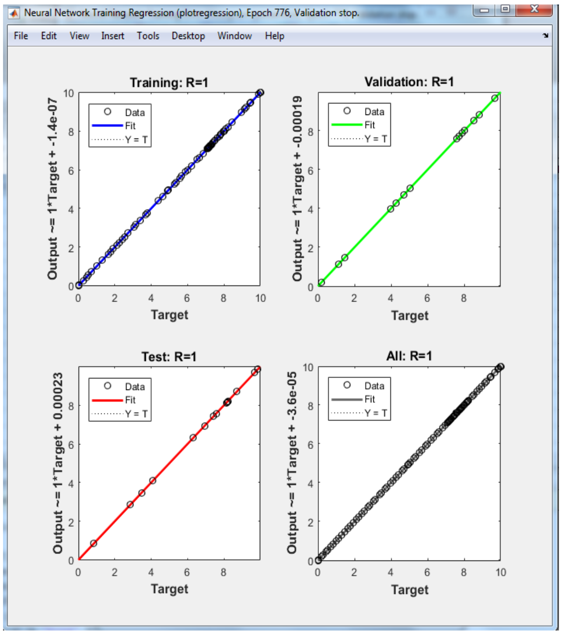

Figure 11. Training, Test, Validation and Overal performance values of ANN model *(Tırnaklı bağlantıların sökme ve çözme kuvvetlerinin belirlenmesi için geliştirilen YSA modelinin Training, Test, Validation ve Overal performans değerleri)*

5. CONCLUSION *(SONUÇLAR)*

In this study; In this study, it has been studied on the model of artificial neural networks by the method of friction coefficient and the type of material of the fastening fasteners. The numerical values obtained from the graph shown in Figure 4 form the database of Artificial Neural Network (ANN) model. In Matlab environment, many different learning algorithms and layers have been changed and the best performing model has been determined. In this model; a practical method has been developed that provides the determination and calculation of clamping and unwinding forces for claw connections by obtaining MEP% = 0.624073, RMSE = 0.008977 and R2 = 0.99999.

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ÖZGEÇMİŞ

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Fulya Erdemir was born in Ankara, Turkey, on 22 February 1994. She completed her primary, secondary and high school education in Ankara. She started her higher education in 2012 in Eskişehir Osmangazi University Mechanical Engineering Department. She graduated from Eskişehir Osmangazi University, Department of Mechanical Engineering in 2017. In 2017, she started her post graduate education at Gazi University, Institute of Science and Technology, Department of Industrial Design Engineering. She still continues her graduate studies in the same department.

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He was born in 1971 in Malatya. He completed his primary, secondary and high school education in the same city. In 1991, he started his undergraduate education at Gazi University, Faculty of Technical Education, Mechanical Education Department. In 1994, he graduated from Gazi University Faculty of Technical Education Department of Mechanical Education. He completed his master's degree in 1996 and his doctorate in 2003. He graduated from Gazi University, Institute of Science and Technology, Department of Mechanical Education. In 1995, he started to work as a research assistant at the Faculty of Technical Education of Gazi University. In 2009, he worked as an assistant professor at the same faculty. In 2013, he was appointed as assistant professor at Gazi University, Faculty of Technology, Department of Industrial Design Engineering. In 2016, he became an associate professor in mechanical engineering. He still works as an associate professor in the same department.