

DETERMINATION OF YIELD STRENGTH OF 2014 ALUMINUM ALLOY UNDER AGING CONDITIONS BY MEANS OF ARTIFICIAL NEURAL NETWORKS METHOD.

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As known, 2XXX and 7XXX Aluminum process alloys can have high strength values by means of precipitation hardening heat treatment. Determination of the precipitation hardening conditions which can give the most suitable strength values of an alloy, requires numerous tests. But the results of this process which require long time and high cost can be obtained in a shorter time and at a lower cost with less data by means of Artificial Neural Networks method. Since this method is used, less number of experiments and therefore less data is needed. Then other values are found by means of Artificial Neural Networks method.

In this study, Artificial Neural Networks were educated with yield strength values of 2014 Aluminum alloy obtained at different aging times and at 150, 190, 232, and 260°C after taken into solution at 500°C. Afterwards, yield strengths of alloy at different temperatures were determined by means of Artificial Neural Networks method.

1. INTRODUCTION

In many industrial fields, Aluminum and its alloys are widely used as suitable materials for constructions needed to be lightened. Aluminum, with over 100 possible alloying elements, even leaving out the elements that are very rare or very poisonous, millions of useful alloy combinations would seem possible. The possibilities are quite limited if small alloy variations are ignored. Alloying elements are usually added to aluminum to increase its strength, although improvements in other properties are very important. The two most commonly used methods of increasing the strength of aluminum alloys are to:

- Disperse alloying elements or elements in solid solution and cold work the alloy; work hardening alloys,
- Dissolve the alloying elements into solid solution and precipitate them as coherent submicroscopic particles: precipitation-hardening alloys.

Only nine elements have a maximum solid solubility greater than 1 wt% and have substantially lower solubilities at lower temperatures. Of these nine elements, silver, gallium, and germanium are expensive and lithium, because of processing difficulties, is presently used only in special alloys. This leaves five elements: zinc, magnesium, copper, manganese, and silicon, which form the basis for the principal commercial aluminum alloys [1]. These are used in various combinations, as shown in Fig. 1.

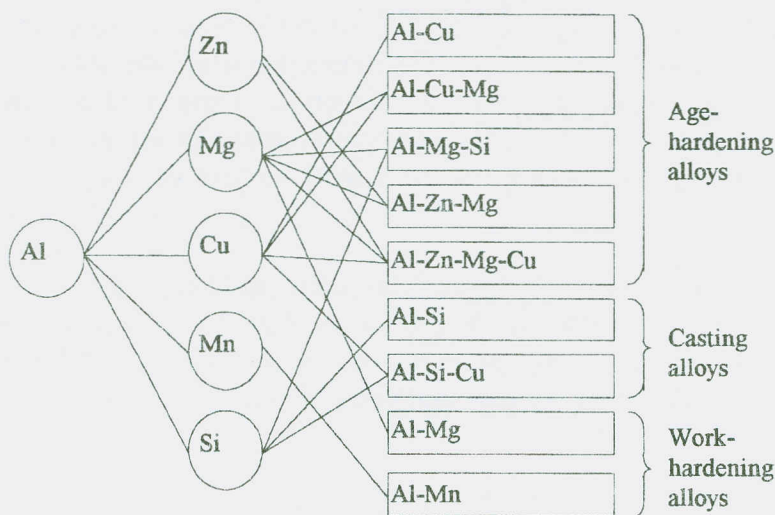


Figure 1. Principal aluminum alloys [2].

2. PRECIPITATION HARDENING

Precipitation hardening, or age hardening [3-6], is produced by solution treating and quenching an alloy in which a second phase is in solid solution at the elevated temperature but precipitates upon quenching and aging at a lower temperature. The age-hardening aluminum alloys and copper beryllium alloys are common examples. For precipitation hardening to occur, the second phase must be soluble at an elevated temperature but must exhibit decreasing solubility with decreasing temperature. By contrast, the second phase in dispersion-hardening systems has very little solubility in the matrix, even at elevated temperatures. Usually there is atomic matching, or coherency, between the lattices of the precipitate and the matrix, while in dispersion-hardened systems there generally is no coherency between the second-phase particles and the matrix. The requirement of a decreasing solubility with temperature places a limitation on the number of useful precipitation-hardening alloy systems.

Many of the Aluminum alloys can be hardened by precipitation hardening. With convenient alloying and heat treatment, yield strength can be increased as 40 times compared to high purity Aluminum.

3. ARTIFICIAL NEURAL NETWORKS (ANN)

Computers can do numeric calculations at a high speed and accuracy that humans can not achieve. But they are insufficient and slow compared with human, in doing intelligent processes as learning new things using previous experiences needing human intelligence and thinking, and interpreting learned things. Numerical computers can also be programmed for doing intelligent processes. But this needs processing excess and different information and programs are too much complex. Studies on development of computer systems which can make processes requiring human intelligence and thinking, have abilities as perception, interpretation and decision making are called "Artificial Intelligence Studies". Although it is not

at a sufficient level, here, the aim is to simulate human brain. The human brain makes calculation and evaluation processes by means of numerous neurons connected to each other with complex links. Researchers have developed Artificial Neural Network for facilitating Artificial Intelligence studies by examining these neurons that are basis of brain [7]. Neurons in human brain are very simple compared to processors at computers but they are parallel working units in large number. Here signifying simple units called neurons as a whole is important. Every processing unit does a part of a work instead of doing the whole work at once.

But neural networks can identify whole models solve problems requiring thinking, learn something from experiences. Sharing of the jobs to neurons by processing unit and parallel execution is a speeding and powering property of neural networks. All units on a neural network system have the following four essential parts (Figure 2).

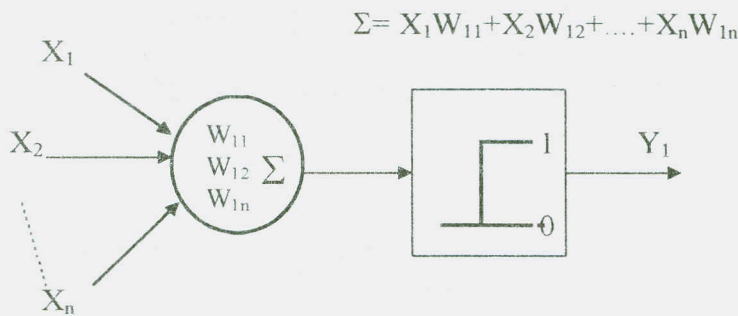


Figure 2. Artificial Neural Network Model: 1. Input Connections: Activity values of the effects of other units to the unit. 2. Total Function: The function that gets different input values as a single value. 3. Threshold Function: The function that translates the total value of input activities to the output activity (If total value is below the threshold value output is 0, otherwise output is 1) 4. Output Connections: Final calculated value of the unit. It is the input value for the other units connected to it.

In many Artificial Neural Network “Learning” occur by changing connection weights. It is essential in learning to change weights according to a good model. In this study supervised learning system was used. The principle in supervised learning is; firstly to train the learning system with true examples of input and output then to be able to take true information when asked. Also intermediate values that are not trained can be obtained. There are many supervised learning Artificial neural network systems. The most known and used ones are: Perceptron, Multilayer Perceptron, and Hopfield Network. We used multilayer perceptron network. Multilayer networks have more than one layer called as hidden layer between input and output layers. For it cannot be known what kind of information is wanted from hidden layer units, it is not easy to give error signal at the output of the hidden units. For this reason the effect of every hidden unit to the errors of output unit must be evaluated. This is done by taking the total of the weights of error signals of the output units connected to line hidden unit, for every erroneous unit. In networks having more than one hidden layer error signals of every layer are subtracted from the previous corrected signals and this process is recurred. Weight

correcting process begins from the weights belonging to the output level and continues till to the input layer. At the end, network does many errors but it learns something from these errors and continues the process until finding the desired value. This method is called “Back Propagation Algorithm” [8, 9]. It is the Artificial neural network algorithm used in this study.

4. USAGE OF ARTIFICIAL NEURAL NETWORKS FOR THE DETERMINATION OF THE YIELD STRENGTH OF AGED 2014 AL ALLOYS

It is needed to determine the convenient aging conditions for achieving high hardness/strength values of Aluminum alloys. For this reason, many aging processes of different temperature and time are applied to the alloy. The temperature and time giving the maximum value for that alloy is determined by measuring the hardness/strength values of the material obtained. This determining process done many times for every alloy needs long time and high costs.

Hardness/strength values obtained from few pretests are used as input value at Artificial Neural Networks method and the network is trained. After this process, Artificial Neural Networks gives the hardness/strength values according to the given different temperature and time values in a short time and without any cost.

The Artificial Neural Networks is trained by giving the yield strength values [1, 10, 11], at isothermal aging curves at 150, 190, 232 and 260°C after taking 2014 alloy to the solution at $500\pm3^{\circ}\text{C}$, as input values. After that as an example, the yield strengths at intermediate temperature values of 176 and 204°C and at high temperature value of 288°C are calculated (Fig. 3). It is seen on the graphics that the yield strength values found by Artificial Neural Networks are in harmony with the values obtained by the tests.

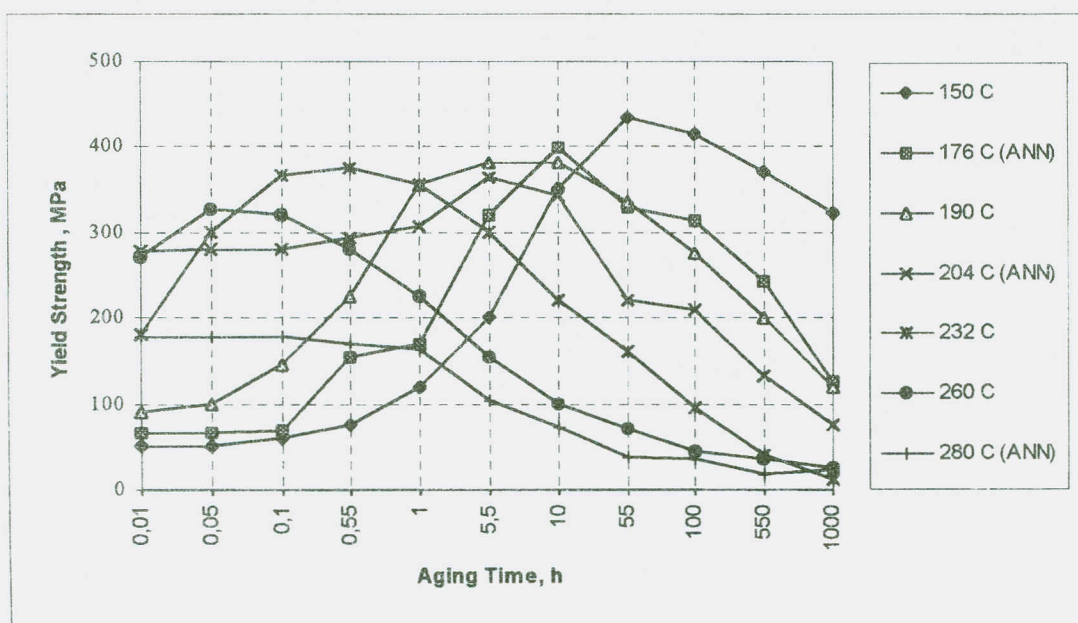


Figure 3. Isothermal aging curves of 2014 alloy found by tests and A.N.N. Test temperatures are 150, 190, 232 and 260°C; the temperatures used at calculation, in A.N.N. are 176, 204 and 288°C.

"Generalized Delta Rule" was chosen as the learning rule at multilayer feed forward network used in the study. The "aging temperature and time" values of 2014 alloy were given to the input layer of the network. At the output layer there was "Yield Strength" value. The best learning ratio (ϵ) signifying the learning gain was 10 and the momentum constant α signifying the learning speed was 0.1.

5. RESULTS

Instead of doing aging tests with many test specimens, with less test and giving these test results to "artificial neural networks" as input as input values, optimum aging conditions of Al alloys, of which mechanical properties improved by precipitation hardening method, can be determined. The strength values which can be obtained from after aging conditions by training with this values, can be determined with a great accuracy (at 100.000 iteration with %96 accuracy).

REFERENCES

1. Hatch, J., E.; "Aluminum: Properties and Physical Metallurgy", American Society for Metals (1984), Ohio, p. 139, 203.
2. Altenpohl, D.; "Aluminium Viewed From Within", Aluminium-Verlag, Dusseldorf (1982).
3. Martin, J. W.; "Precipitation Hardening", Pergamon Press, New York, 1968.
4. Nicholson, R., B.; Thomas, G.; Nutting, J.; "Electron-Microscopic Studies of Precipitation in Aluminium Alloys", Journal of Inst. Metals, Vol. 8 (1958-59), p.429.
5. Bargel, H. J, Schulze, G.; "Werkstoffkunde, VDI-Verlag GmbH, Düsseldorf, 1983.
6. Dieter, G., E.; "Mechanical Metallurgy", McGraw-Hill Book Company, London, 1988.
7. Lippmann, R.; "An Introduction to Computing with Neural Networks", IEE ASSP, April 1987.
8. Karlık, B.; "Yapay Sinir Ağları ve Uygulamaları", Ders Notları, CBÜ Fen Bilimleri Enstitüsü, Manisa 1995.
9. Atik, E., Karlık, B.; "Malzemelerin Aşınma Davranışlarının Belirlenmesinde Yeni Bir Yaklaşım", GAP I. Mühendislik Kongresi, Bildiriler Kitabı, Şanlıurfa 1996, p.328.
10. Singh, S., Goel, D. B.; "Influence of Thermomechanical Ageing on Tensile Properties of 2014 Aluminium Alloy", Journal of Materials Science, 25, 1990.
11. Van Vlack, L., H.; "Elements of Materials Science and Engineering", Addison-Wesley Publishing Company, Massachusetts, 1989.