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ANN (ARTIFICIAL NEURAL NETWORK) APLICABILITY FOR MODELING AL 6061 ALLOY PROPERTIES

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Abstract: *The majority of newly developed techniques in the aluminum industry are sometimes destined to make special products which require an elaborate investigation of alloy properties, therefore wasted time and additional costs. In the end, the new techniques cannot specify or simulate the required microstructure, optimal parameters, optimal alloy composition in order to improve the new processes which include Al6061. The majority of Al6061 (Al6xxx series) improvements are closely related to their mechanical properties (which also depend on the microstructural characteristics). Therefore, we can use the process-structure-properties simulation methods for the Al6061 alloy, with good results over the physico-mechanical characteristics or in the recycling process. In this article, using ANN (Artificial Neural Network), we have analyzed the implications which the chemical composition of Al6061-T6 has over the mechanical properties and elaboration temperature. This correlation between the mechanical properties and chemical composition has a high importance for establishing the right path for a product, without additional costs or wasted time, but also improving certain characteristics of the alloy.*
Keywords: Artificial Neural Network , Al6061-T6, mechanical properties

1.INTRODUCTION

The majority of newly developed techniques in the aluminum industry are sometimes destined to make special products which require an elaborate investigation of alloy properties, therefore wasted time and additional costs. In the end, the new techniques cannot specify or simulate the required microstructure, optimal parameters, optimal alloy composition in order to improve the new processes which include Al6061. The majority of Al6061 (Al6xxx series) improvements are closely related to their mechanical properties (which also depend on the microstructural characteristics). Therefore, we can use the process-structure-properties simulation methods for the Al6061 alloy, with good results over the physico-mechanical characteristics or in the recycling process.

The thermic treatment has an important role in obtaining the desired alloy, with desired physico-mechanical characteristics. It is important to know the fact that the solutions of the thermic treatments are important in order to establish the characteristics of the alloy but also to optimize the process parameters according to a specific path.

The European Union has a high number of Al alloys, each one of them with specific structure which can undergo ANN simulative – predictive techniques. The idea of ANN applicability is optimizing the process parameters and Al6061 alloy composition in order to obtain a separate combination which can be used on a large scale.

In this article ANN is used to predict the correlation between the mechanical properties of the Al6061-T6 alloy. The objective is developing an ANN method which can provide data related to process parameters and Al-6061-T6 composition influence over the mechanical properties in order to use the alloy for new purposes.

The aluminum is an important element with a complex applicability in several industries, nationally and internationally. Al6061 is used on a large scale for different purposes because of its properties: $2.71 g/cm^3$ density, Young: 68.9GPa, Poisson: 0.33μL. It is the most commonly used aluminum, although it is split in different categories: 6061, 6061-T4, 6061-T6 (each one having physico-mechanical properties which differ based on elaboration and destination). The maximum resistance is somewhere at 300MPa, 8% elongation, 77^oF conductivity at $152W/m.K$, endurance limit up to 100MPa.

Al6061 is used in building certain aircraft parts (wings, fuselage), passenger planes, sometimes Al2024 is more resistant, but Al6061 has a better machinability and high corrosion resistance. It is also used for building yachts, boats, engine and wagon parts, bicycle parts, fishing products.

2. ANN MODELING

Using ANN requires determining the relationship between the Al6061-T6 properties, alloy composition and process variables. Generally, ANN is characterized by: architecture, activation functions, used algorithms and transfer functions.

In order to describe the ANN model we can consider a black box in which we input data and based on defined criteria it offers us information correlated to the processes-structure-properties line. ANN structure is characterized by the number of inputs and number of neurons in each input (Figure 1). Simplified, ANN consists of: inputs, hidden data (processing) and outputs.
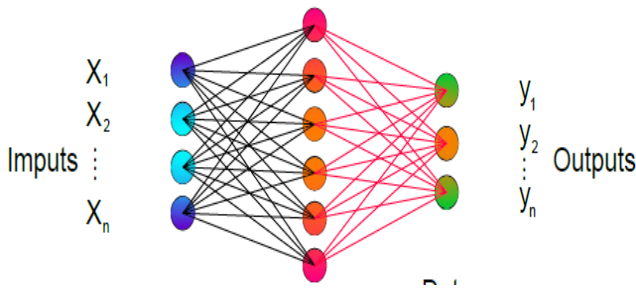
Figure 1. *ANN general architecture*

Table 1. *Al6061 parameters used for ANN (input parameters for the 6xxx series)*

Alloying elements	Mg	Si	Cu	Zn	V	Ti	Fe	Mn	Cr
Number of alloys containing this elements	40	30	21	14	0	12	16	13	12
Range, (%weight)	0-1.4	0-1.8	0-1.2	0.025	0	0-0.2	0-0.7	0-1.1	0-0.5

Modeling and simulating ANN for Al6061-T6 alloy present the following steps: data collecting, processing, NN training, testing NN training model and predicting simulation used build NN models.

It is also important to limit the errors of approximation and specific input data adjusting, and the whole process repeats until we obtain a criterion or error-free function. Inside ANN a valid function transforms the input data in output values (which have a $y = ax + b$ linear variation).

The input parameters in order to study the processes-structure-properties system for Al6061 are directly related to the chemical composition, quantity, element combination for alloying. For each element of $Al6x_1x_2x_3$ series, the first number indicates the series, x_1 – alloy element modified in a pre-existent alloy, x_2x_3 – special alloy element.

Table 2. *Physical and elastic parameters of Al6061-T6*

Al6061	Elastic		
	E	G	v
	70000	26300	0.33
	Physical		
	T_{sol}	T_{liq}	Cp	a	ρ	ρ_{el}	λ	EC
	580	650	895	23.3	2700	40	166	43

Key to Parameters:

E	Modulus of elasticity	MPa
G	Modulus of rigidity	MPa
v	Poisson's ratio	
T_{sol}	Solidus temperature	°C
T_{liq}	Liquidus temperature	°C
C_p	Specific heat capacity	$J\,kg^{-1}\,K^{-1}$
a	Coefficient of thermal expansion	$\mu m\,m^{-1}\,K^{-1}$
ρ	Density	$kg\,m^{-3}$
ρ_{el}	Resistivity	$n\Omega\,m$
λ	Thermal conductivity	$W\,m^{-1}\,K^{-1}$
EC	Electrical conductivity	%IACS

Major alloying elements for Al6061-T6 are Mg and Si, and the chemical composition for the analyzed alloy is presented in Table 1. Physical and elastic characteristics are highlighted in Table 2. They have been taken from specialized articles, analyzed and used in the simulation.

3. RESULTS AND DISCUSSIONS

ANN procedure has been used for predicting the correlation between the processes and the mechanical characteristics of Al6061-T6 alloy. We can analyze the process at different temperatures because the alloy can present different microstructures, therefore it has different mechanical properties.

According to Figure 2 we can analyze the predicted and experimental values of the Al6061-T6 alloy depending on the mechanical resistance properties. The differences are very subtle, approximately 0.214 (statistically, there are no major differences between the two methods).
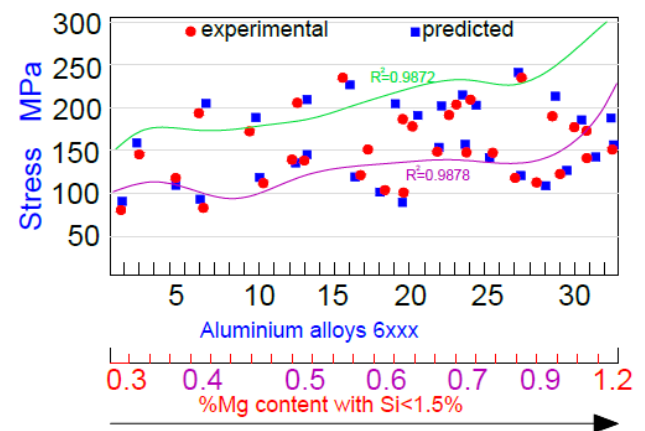

Figure 2. *Experimental data variation as opposed to the predicted ones and evolution towards Mg alloying*

Figure 3 presents the influence of alloying elements from the chemical composition of the Al6061-T6 alloy over stress distribution. The calculated radius of the graphics $R^2_1=0.9872$ and $R^2_2=0.9878$, close to 1, show a high precision of tension and stress values from the graphic. Practically, these curves can be used to approximate the desired chemical composition and to achieve certain mechanical properties. Costs and work time are also very important, therefore they must be minimized. Additionally, Figure 4 presents the area based on ductility evolution depending on alloy composition. The most important areas are rendered for unidirectional and alternative tests.
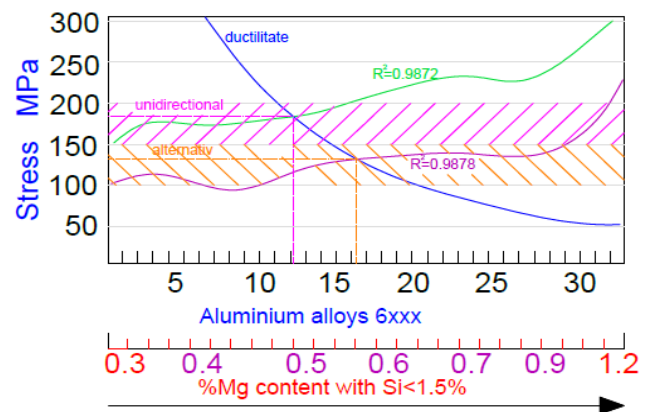

Figure 3. *Influence of alloying elements from Al6061-T6 chemical composition.*
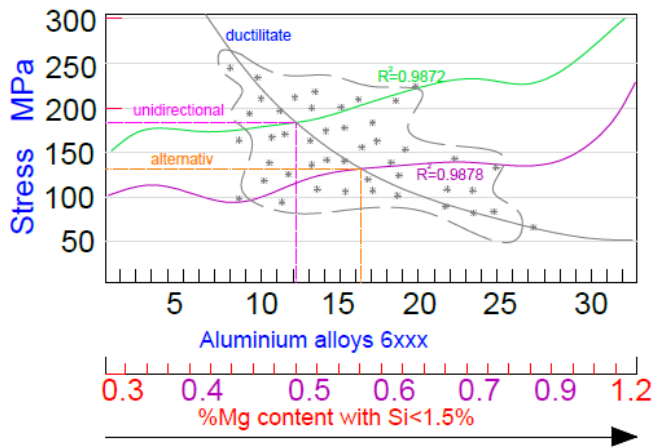
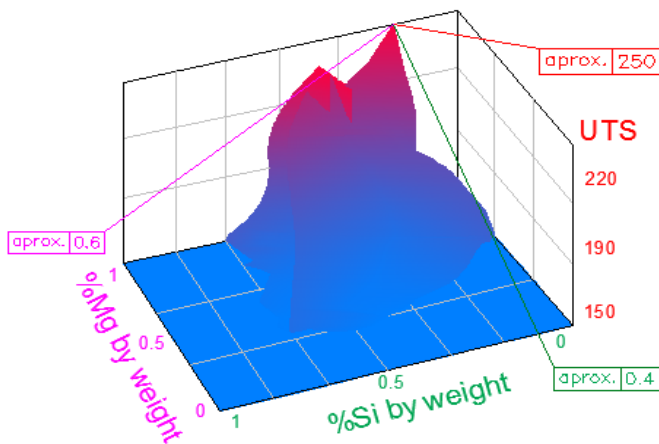**Figure 4**. Ductility variation based on alloying elements for Al6061-T6

Figure 5. ANN simulation models for chemical composition (alloying elements) influence over mechanical properties

Figure 5 proves that using ANN for Al6061-T6 we can predict the influence of the chemical composition over the mechanical properties. Maximum values are rendered on the graphic.

4. CONCLUSIONS

ANN models are used to correlate characteristics such as: structure-processes-properties used for Al6061-T6 material. Therefore, we can remind the following:

Ξ ANN modeling is important for developing pieces and structures made of Al6061-T6 using product mechanical properties information.

Ξ the results of the simulation can be used to determine the optimal composition for Al6061-T6 in accordance with the destination of the final product.

Ξ the ANN method has been used to obtain approximate solutions without additional costs or wasted time.

Ξ ANN predictions, such as the ones in this article, can be used as inspiration source for various design and elaboration projects, reducing production costs to 0.

Ξ the results from this article can be used in different industries for choosing Al6061 alloy domain used based on parameters such as ductility, alloying elements.

Ξ the research in this article can be extended therefore obtaining information related to temperature and chemical composition

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