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Application of artificial neuron networks for the assessment of strain history impact on mechanical properties of semi-products used in forges and in mechanical engineering operations

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The material for square billets and rod iron production in forging is traditional ingot or COS ingot made of carbon steel or low-alloyed steel melted in oxygen converters or electric furnace, along with outside furnace processing. Requirements that are demanded from the part of forges and mechanical operations are described in relevant arrangements concluded between a deliverer of billets and its receiver. The quality of billets delivered to forges and mechanical openings depends on two factors, that is the quality of mill feedstock prepared for plastic treatment in steel mill and the kind of processing in steel mill itself. The quality requirements that are demanded from each semi-product to be processed later in mechanical engineering enterprises and forges contain the description of finished metallurgical research along with the mechanical features examination. In works (1,2,3,4) some experimental research has been carried out with relation to the impact of conditions, connected with the manufacturing semi-products process, on structure and mechanical features of the finished product. On the basis of the results of the above works as well as the study done by the authors alone, a new methodology has been proposed as regards the distortion process impact assessment for mechanical features of a semi-product. A new computer program has been established based on artificial neuron networks for optimal forecast of the process degree which guarantees receiving of assumed mechanical features.

1. RESEARCH WORK CONCLUDED

The objective of the empirical research was to define the process degree impact on the level and homogenity of microstructural parameters and the features of mechanical semi-products. In table No. 1 different kinds of steel have been compiled as well as the symbols of the samples taken so as to define the microstructure and features of semi-products used during the subsequent treatment in mechanical engineering enterprises and in forges.

Table 1. Symbols of samples and sorts of steel rods under examination

No	Sort of steel	Sample No. Melting No.												
		ϕ50	ϕ55	ϕ60	ϕ65	ϕ70	ϕ75	ϕ80	ϕ85	ϕ90	ϕ95	ϕ100	ϕ110	ϕ120
1	C15			3/1 010316						9/1 032680	10/1 032672	11/1 032679	12/1 020712	13/1 020712
2	C45	1/2 922483	2/2 922387	3/2 922484		5/2 913382		7/2 031565	8/2 020851		10/2 012280	11/2 031565	12/2 020581	13/2 922480
3	C60				4/3 912986									13/3 020961
4	St52-3	1/4 021268	2/4 010275	3/4 031380	4/4 911092	5/4 021663	6/4 021270		8/4 011598			11/4 031378	12/4 020814	13/4 020814
5	40H		2/5 282511	3/5 509546		5/5 911343	6/5 17930						12/5 511008	13/5 285371
6	40HM				4/6 932233		6/6 285272							13/6 284602
7	16HG	1/7 282652		3/7 282652		5/7 284102					10/7 511851			

During the industrial process of rolling of the examined semi-products the process distortion conditions due to temperature have been registered. Some samples were taken from the rolled rods and afterwards the rods selected became the object of analysis, metallurgical and metallographic research as well as the object of mechanical qualities research. Then, the size of ferrite grain has been determined along with the break-down of hardness (by Vickers and at 300 N) on the section of the examined products.

On the basis of the collected results, the data base has been made up which includes measured mechanical qualities and matching them the registered, real conditions of process due to temperature distortion. Data collected in data base has been used to build up a model and computer program based on algorithms of neuron nets so as to forecast the optimal kind of processing. It results from the definition itself that the kind of processing must guarantee qualities in accordance with the requirements of the order. The crucial factors that define the level and the break-down of mechanical qualities in semi product are chemical composition and cooling and processing conditions. Because the manufacturer is unable to fully control the chemical compound of the mill feedstock delivered, so the only way by which means it is possible to control the mechanical qualities is by hot plastic processing closely linked with a proper cooling method.

2. ANALYSIS OF THE RESEARCH RESULTS

On samples selected and within the industrial research there has been completed metallographic research, that is an average size of ferrite grain. Also, there has been carried out the research of mechanical qualities (hardness measured by HV).

In the case of steel quality C15 no substantial impact on the final size of ferrite grain has been observed. The differences observed in the size of ferrite grain between the layer close to the surface and the middle templet layer are very small and amount to 4,2 till 5,3 .μm. Much bigger differentiation in the break-down of ferrite grain for the cross-section has been noted for steel quality C45, 40H, St52-3, 16HG. It follows from the microstructural analysis for steel quality C45 that the smallest difference in the size of grain between the surface and the middle of the sample has been observed in the case of processing level 7,8 and 10, what corresponds to the greatest values in the steel mill that has been examined. The greatest spread in the medium size of ferrite grain has been received for the processing level 3,8 (13,6μm). For steel quality St52-3 and 40H there has been observed the greatest differences in the size of ferrite grain between the surface and the middle of templet. The biggest difference in the size of grain has been observed for the processing level 2,6 and 3,8 and that difference amounted to 9,3-13,6 μm.

In fig.1 there have been exemplified the results of metallurgical research done with samples from steel quality C45.

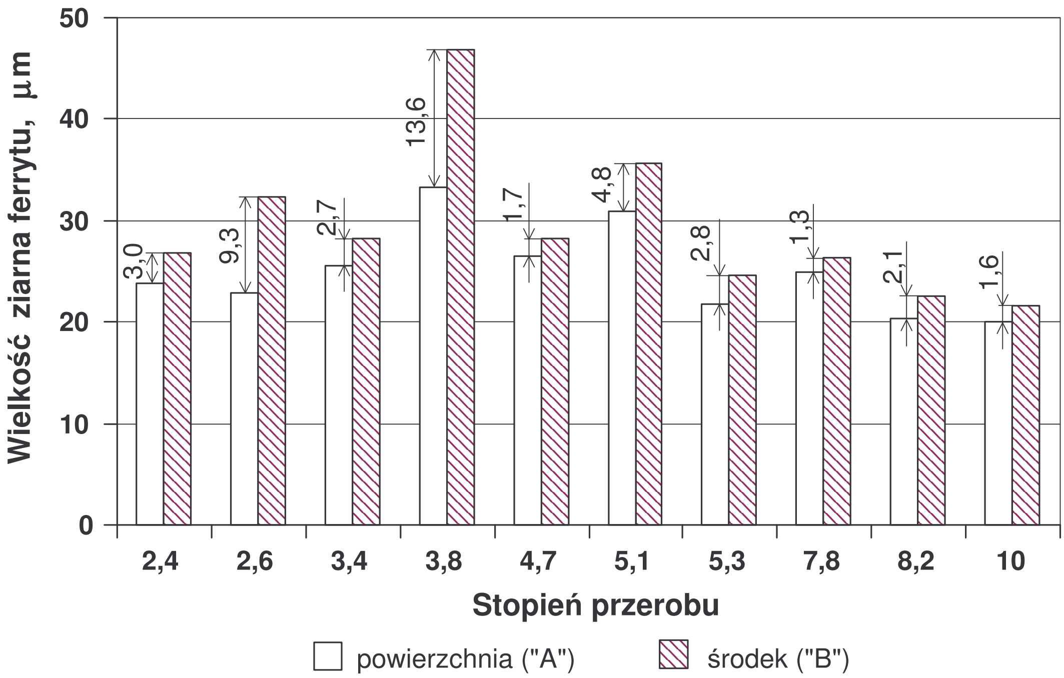

Fig.1. Results of metallographic research for steel quality C45

After the analysis of results due to the industrial research, the system for technological process optimization based on neuron nets has been worked out. The main purpose of this system relies on forecasting the optimal processing level so as to ensure receiving of assumed mechanical characteristics. In chart No.2 the ideal pattern of the system has been presented.

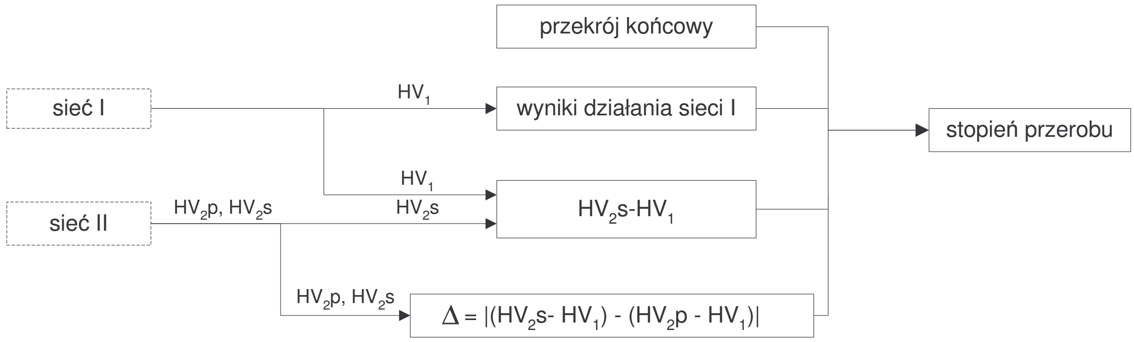

Fig.2. The ideal pattern of the system

Program based on the model incorporated in Fig .2 consists of neuron nets that split the solution of the discussed problem into several stages. The main purpose of the first two stages is to forecast data which constitute the input to the last module which in turn forecasts the processing level that is the basic hardness of material following the composition of steel HV1 and the changes in hardness as a result of temperature distortion conditions for HV2p, HV2s gradient hardness between the surface and the middle of the rod Δ_{Hv}.

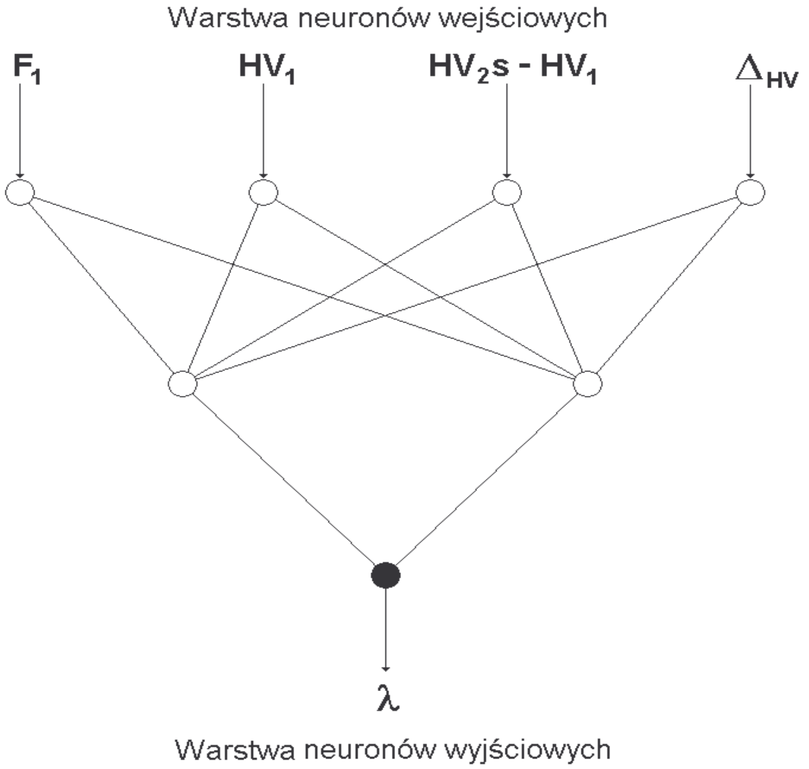

Fig.3. Pattern of neuron net used to forecast optimal rod processing degree

For the final cross-section (F1) and parameters describing the break-down and the level of mechanical characteristics (HV1, HV2s and .....HV), neuron net in chart No.3 forecasts the optimal value for the processing degree. The equation (1) let us define the initial cross-section of mill feedstock.

$$\lambda = \frac{F_p}{F_k} \Rightarrow F_p = \lambda F_k \tag{1}$$

The value defined in the above described way should be included in the series of types of available cross-section ingots. Accepting the cross-section greater than that te one described by means of the above calculation, raises the processing level above the required minimum what can increase the processing cost. But when we accept the cross-section lower than that described above, it can lead to the increase of mechanical characteristics break-down on the cross-section of the final output.

Table 2. Input data for calculation of the minimal rod processing level

F_1	HV_1	$HV_2s\text{-}HV_1$	Delta HV
7850	96,77	48,14	18,53
5024	96,74	43,73	17,52
6358	98,37	41,42	21,17
9498	94,37	46,65	20,45
7850	94,27	37,29	15,22

In table No.3 there have been exemplified the results of the forecast for the optimal rod processing degree in the case of steel C15.

Table 3. The results of the calculation for the optimal rod processing level

No	Optimal processing degree	Accepted cross-section of mill feedstock
1	4,45	188 x 188
2	6,81	184 x 184
3	5,72	190 x 190
4	3,22	175 x 175
5	3,55	167 x 167

The pattern presented, after expanding its data base for training, can become a useful tool for the department of technology. Thanks to this pattern we are able to choose the optimal mill feedstock level and allow for customers requirements with regard to the quality of billets assigned to further processing in mechanical operations and forges.

3. CONCLUSIONS

The pattern built to forecast the minimal processing level and based on neuron nets let us define minimal processing level which takes under consideration complicated changeability of mechanical characteristics on the cross-section of semi-product assigned to be processed in mechanical operations and forges.

The analysis that has been carried out by means of the pattern based on neuron nets in order to forecast the minimal level of processing enabled us to define the impact of customer's requirements as regards mechanical characteristics on choosing the minimal processing degree. From application of neuron nets to project invention technologies it follows the possibility to diagnose the impact of processing conditions on the level and break-down of mechanical parameters in semi-product, what constitutes a new approach to defining the processing level.

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