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PROGNOSTIC METHODOLOGY OF FORECASTS STEEL PRODUCTION FOR POLAND UNTIL 2022

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The publication presents the prognostic methodology used in forecasting of quantity of steel production. On the basis of empirical data (yearly steel production) from period 2000 - 2017, forecasts of steel production for Poland until 2022 were estimated. The prognostic methodology in the first step consisted in: determining separate forecasts for: steel production in total and BOF steel and EAF steel. In the second step the equations were used: total steel production – (minus) BOF steel = (is) EAF steel and total steel production – (minus) EAF steel = (is) BOF steel. The forecasting methodology adopted was possible because the sum of BOF and EAF processes is the total production (100 %) in the steel sector in Poland.

Key words: steel production, basic oxygen furnace (BOF), electric arc furnace (EAF), methodology, forecasts.

INTRODUCTION

Forecasting production volume is a component of the production strategy [1]. Forecasts inform about the production volume. Steel production since 2002 in Poland is carried out using two technologies: BOF - Basic Oxygen Furnace and EAF - Electric Arc Furnace. Total steel production is the sum of BOF steel and EAF steel. The publication presents forecasts of steel production calculated on the basis of statistical methods with using such mathematical equation: Total steel production = BOF steel + EAF steel. Basic models for forecasting steel production in Poland based on time series were used: historical data on steel production in Poland in 2000 - 2017.

EMPIRICAL DATA FOR PROGNOSTIC METHODOLOGY

Empirical data is steel production in Poland in 2000 - 2017 (annual production volume in million tonnes - Mt). Based on the evaluation of the distribution of empirical points (Figure 1) corresponding to the observed value of the time series, forecasting methods for simple linear and nonlinear trends were discarded. There was also no development trend with the trend growing or with a declining trend, the empirical values oscillate around the average annual production of steel, which in the period under study was 9,07 million tonnes. The average annual share of converter steel in the average annual steel production in the analyzed period in Poland was 58,4 %, and electrical steel 41,6 % [2].

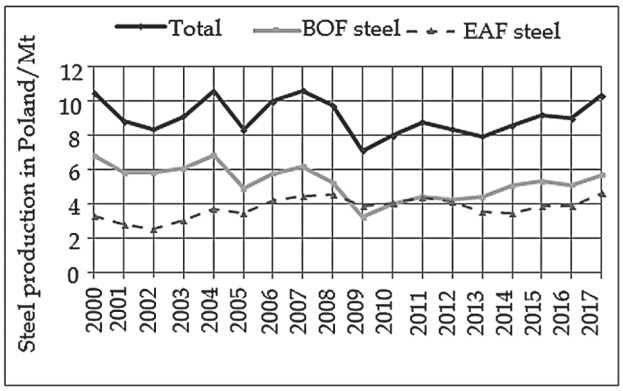

Figure 1 Steel production in Poland in 2000 - 2017 [2]

USED PROGNOSTIC METHODS

Taking into account the course of the trend (Figure 1), such basic prognostic methods have been used to develop the predictions [3, 4]: additive naïve method, multiplicative naïve method, simple moving average for time series with different value of k-points (k = 2 or k = 3), weighted moving average for time series with different value of k-points (k = 2 or k = 3) and different weights (w_i), simple exponential smoothing Brown's model for different start points y_t and simple single exponential smoothing (Brown's model), exponential autoregressive model for different value of k-points and different value of l-points, Brown's double exponential smoothing (linear) and Brown's triple exponential smoothing (quadratic), Holt's linear trend model with additive trend for different start points (S_1), Holt's linear trend model with multiplicative trend for different start points, Holt's linear trend model with additive damped trend for different start points, Holt's linear trend model with multiplicative damped trend for dif-

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ferent start points, Holt's quadratic trend model with additive formula for different start points, advanced exponential autoregressive models, autoregressive models (AR) creeping trend method - prediction using the harmonic scales method.

FORECASTS OF STEEL PRODUCTION

At this stage of forecasting the volume of steel production for Poland, the methodology was used to build separate forecasts for: total steel production, BOF steel and EAF steel. The distribution of obtained forecasts is shown in Figure 2.

Research results:

1 Forecasted steel production for Poland is around 10 million tonnes per year (optimistic scenario is created by forecasts with annual steel production exceeding 10 million tonnes).
2 Forecasted steel production using BOF technology is higher than the forecasted steel production using EAF technology (compliance with the distribution of individual technologies in steel production in Poland, in 2000 - 2017 BOF steel share in total production was 58 %).
3 The forecasted trends for steel production for Poland are growing. Until 2022 (the adopted forecast time limit), it is possible to assume an increase in steel production in Poland.

METHODOLOGY: TOTAL STEEL PRODUCTION = BOF STEEL + EAF STEEL

Based on the obtained forecasts, two variants of their verification were used:

1 Forecasts of total steel production – (minus) forecasts of BOF steel = (is) EAF steel
2 Forecasts of total steel production – (minus) forecasts of EAF steel = (is) BOF steel.

The use of the above form of determining the production volume (quantity) was possible because both productions: BOF steel and EAF steel constitute the total production of the steel sector in Poland. Variant No. 1 consisted in building forecasts for total steel production and production in converters (BOF) and estimating the forecast for the production of steel produced in arc furnaces (EAF). Variant No. 2 consisted in building forecasts for total steel and EAF steel production and estimating forecasts for the production of steel produced by BOF technology. The forecasting methodology adopted by B. Gajdzik [5, 6] is innovative, and its application enables multi-variant forecasting, while meeting the assumption that the total production is carried out using two key production technologies, whose sub-productions constitute combined production (100 %).

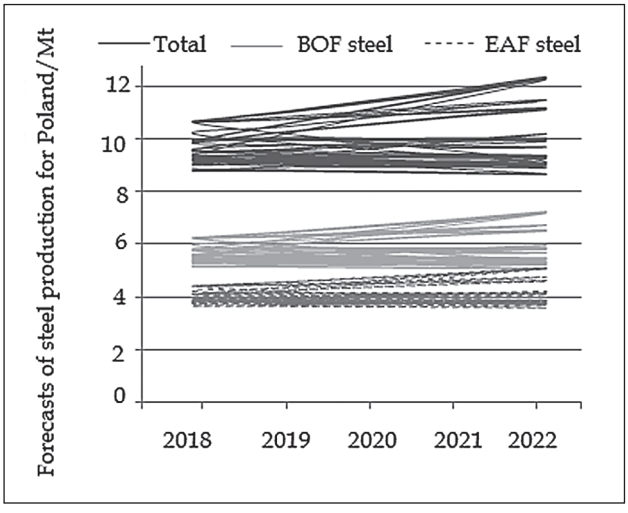

Figure 2 Forecasts of steel production for Poland in 2018 - 2022

The situation referred to in this publication occurs in many countries around the world. According to the data of the World Steel Association [7], steel manufacturing technologies: BOF and EAF are among the key on the global steel market. In 2017 the share of steel produced in converters accounted for almost 75 % on a global scale, and in the EAF processes around 25 %. The share of steel produced in the open hearth furnace is small at 0,4 % [8]. The share of open hearth furnace in total steel production in Poland in 2000 - 2002 was insignificant and amounted respectively to 0,4 %, 0,25 % and 0,09 % (nowadays in Poland and UR this technology is not used).

More information about steel production in the world, Europe and Poland in Table 1. The forecasting methodology presented by the main author can be implemented by the steel industry in countries where two technologies are used: BOF and EAF. The use of several variants of production forecasting allows to increase the reliability of forecasts and broadens the scope of creating possible production scenarios for the steel industry.

Table 1 **Steel production according to used technologies in 2000 – 2017/% [7]**

	World		Europe (UE)		Poland	
Year	BOF	EAF	BOF	EAF	BOF	EAF
2000	61,7	33,9	62,4	37,1	64,7	31,3
2001	62,3	33,6	61,3	38,4	66,1	31,9
2002	62,5	33,8	62,0	37,7	69,3	30,7
2003	63,1	33,5	62,2	37,5	66,6	33,4
2004	63,5	33,3	61,4	38,2	64,8	35,2
2005	65,3	31,9	61,3	38,4	58,7	41,3
2006	65,7	31,7	59,6	40,1	57,7	42,3
2007	66,7	30,9	59,5	40,1	58,3	41,7
2008	67,0	30,8	58,3	41,4	53,7	46,3
2009	70,7	28,0	55,9	43,6	45,4	54,6
2010	69,4	29,5	58,5	41,1	49,9	50,1
2011	69,4	29,6	57,4	42,6	50,4	49,6
2012	70,5	28,8	58,2	41,8	50,6	49,4
2013	73,4	26,0	60,2	39,8	55,3	44,7
2014	73,7	25,8	61,1	38,9	59,2	40,8
2015	75,3	24,3	61,1	38,9	57,8	42,2
2016	74,3	25,2	60,7	39,3	57,0	43,0
2017	73,7	25,8	60,5	39,5	55,3	44,8

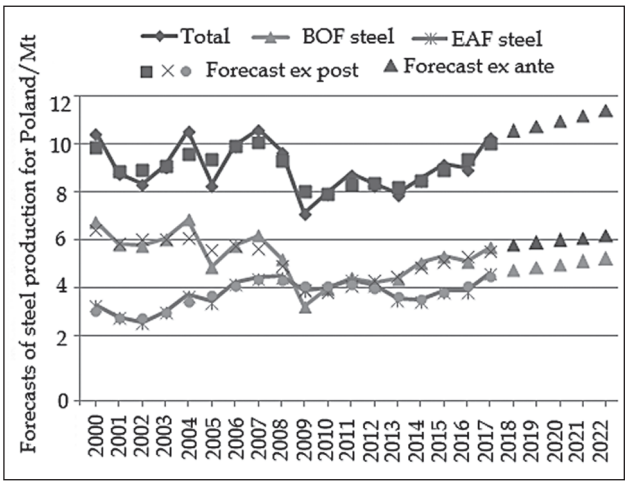

Figure 3 Forecasts of steel production for Poland in 2018 - 2022 by using of method of creeping trend prediction with the harmonic scales method (k = 4) [5]

PRESENTATION OF AN EXAMPLE PROGNOSTIC MODEL

This publication presents the methodology of forecasting using the crawling trend method and forecasting using the harmonic weight method. The model was chosen because of the low error value of ex-post forecasts (Figure 3).

Based on the obtained results (Tables 2, 3), it can be concluded that there are no significant deviations of forecasts obtained using basic statistical models (Table 2) from estimated values, when combined production is the sum of steel production using two base technologies: BOF and EAF (Table 3). Instruction for Table 3: for BOF steel (value in column 3): subtracted from the value in column 1 (minus) values in column 2, for EAF steel (value in column 6): from the value in column 4 subtracted (minus) values in column 5 [5].

BOF and EAF technologies belong to the basic ones in the smelters and will be used in the near future. New generation technologies called unconventional technologies, eg steel production in electrolytic processes of iron reduction, using energy from sources that do not emit carbon dioxide are technologies of little importance (by 2050, the share of unconventional processes in steel production will be small, at around 3 %) [9].

Comparing the obtained forecasts of steel production in 2018 from Tables 2-3 with real steel production in Poland in 2018, it was 10,2 million tonnes, it can be stated that the forecasts are higher by 5,4 % (within the limits of the statistical error).

LIFE CYCLE OF TECHNOLOGY IN STEEL INDUSTRY

Life cycle of technology in steel industry is connected with technological innovation [10]. Taking into account the division of technology according to the criterion of its importance for the development of the (little) steel sector, it is possible to present the further development of BOF and EAF technologies in the steel industry (Figure 4). Taking into account the development of Industry 4,0 [11]

Table 2 **Steel production in Poland in 2000 - 2017 and forecasts of steel production according to used technologies until 2022 by using of method of creeping trend prediction with the harmonic scales method (k = 4)/Mt [3]**

No.	Year	Total steel production	Forecast of total steel production	BOF steel	Forecast of BOF steel	EAF steel	Forecast of EAF steel
No. column		1	2	3	4	5	6
1	2000	10,498	9,888	6,800	6,455	3,285	3,072
2	2001	8,809	8,867	5,823	5,932	2,809	2,762
3	2002	8,367	8,923	5,799	6,058	2,561	2,812
4	2003	9,107	9,123	6,070	6,107	3,037	3,026
5	2004	10,578	9,596	6,858	6,147	3,721	3,458
6	2005	8,336	9,393	4,893	5,665	3,443	3,729
7	2006	9,992	9,941	5,766	5,795	4,225	4,146
8	2007	10,631	10,090	6,198	5,711	4,433	4,379
9	2008	9,727	9,347	5,225	4,993	4,502	4,354
10	2009	7,128	8,048	3,236	3,954	3,893	4,093
11	2010	7,993	7,947	3,995	3,855	3,998	4,093
12	2011	8,776	8,313	4,424	4,134	4,353	4,181
13	2012	8,348	8,367	4,227	4,376	4,132	4,011
14	2013	7,950	8,251	4,399	4,548	3,551	3,670
15	2014	8,558	8,479	5,067	4,893	3,491	3,572
16	2015	9,202	8,958	5,323	5,144	3,879	3,820
17	2016	9,000	9,388	5,110	5,387	3,890	4,142
18	2017	10,330	10,040	5,706	5,557	4,624	4,482
19	2018		10,549		5,800		4,743
20	2019		10,768		5,893		4,863
21	2020		10,987		5,987		4,982
22	2021		11,206		6,080		5,102
23	2022		11,424		6,174		5,221

Table 3 **Steel production in Poland in 2000 - 2017 and forecasts of steel production according to used technologies until 2022 by using presented methodology/Mt [3]**

No.	Year	Forecast of total steel production	Forecast of BOF steel	Total - BOF steel = EAF steel	Forecast of total steel production	Forecast of EAF steel	Total - EAF steel = BOF steel
No. column		1	2	3	4	5	6
1	2018	10,549	5,800	4,749	10,549	4,743	5,806
2	2019	10,768	5,893	4,875	10,768	4,863	5,905
3	2020	10,987	5,987	5,000	10,987	4,982	6,005
4	2021	11,206	6,080	5,125	11,206	5,102	6,104
5	2022	11,424	6,174	5,251	11,424	5,221	6,203

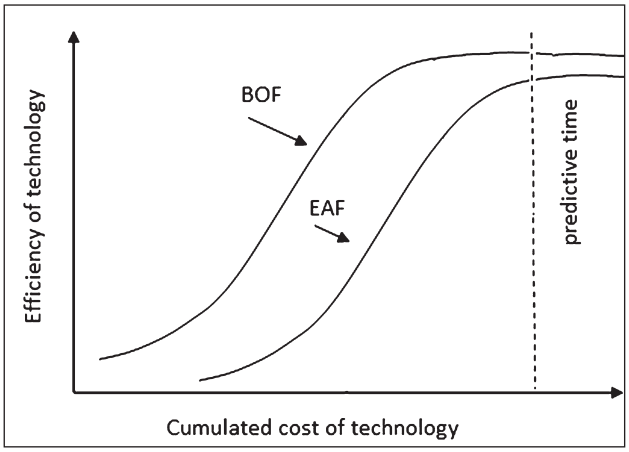

Figure 4 Life cycle of technology for steel industry according to analyzed forecasts of steel production

in the steel industry [12,13], the development of forecasts for steel production broken down by applied technologies is particularly important for planning changes at the level of operational management in enterprises [14, 15].

CONCLUSION

The methodology of making steel production forecasts using a number of statistical methods and verification of obtained forecasts using the equation: Total production = BOF steel + EAF steel

gives a wide picture of the scope of changes in the forecasted phenomenon, which allows accurate verification of the obtained forecasts. The proposed methodology for forecasting steel production using two BOF and EAF technologies is used by Gajdzik for scientific and research purposes [5, 6]. In the Polish steel industry, BF + BOF (converters) and EAF (electric process). Production of BOF steel and EAF steel create all (or almost all) steel production. In the EU countries, all steel production is the sum of the production volume produced in two processes: BOF and EAF. In the world, both BOF and EAF technology are key technologies for steel production and no radical changes in steel production processes are expected in the coming years.

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Note: The responsible for English language J. Jamrozek, Poland.