VARIANTS OF FORECASTS OF STEEL PRODUCTION SIZE FOR POLAND

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Abstract

In the paper the author presented forecasts of steel production size for Poland. The forecasting methodology proposed by the author was two-pronged. Step I consisted in building separate forecasts of total steel production and steel production in the converter process (BOF) and steel production in the electrical process (EAF). Step II uses the principle of differences according to which the total steel production minus steel production produced in oxygen converters is the production of steel produced in electric arc furnaces and vice versa the total steel production minus steel production generated in arc furnaces is the steel production in converters (both productions constitute combined production in the steel sector). Step II consisted of the variant A, which built the forecast for steel production in converters (BOF) and estimated forecasts for the production of steel produced in electric arc furnaces (EAF) and variant B involving the construction of forecasts for the production of steel produced technology EAF and assessing the prospects for production of steel produced by BOF technology. The forecasting methodology adopted by the author 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, the partial outputs of which account for 100 %. Forecasts were built using econometric models on the basis of empirical data for time period: 2000-2015. The author made forecasts of steel production by 2020.

Keywords: Forecasts, steel production, BOF - *Basic Oxygen Furnace*, EAF − *Electric Arc Furnace*

1. INTRODUCTION

Forecasting is a valuable tool in the operations of enterprises. In the conditions of dynamic changes in the business environment, information on future phenomena is particularly important. The forecast is a harbinger, the anticipated effect of something, advanced on the basis of specialist research in a given field [1]. Building forecasts is an integral part of the management process. Forecasts reduce uncertainty in the functioning of enterprises and contribute to the increase in the accuracy of decisions taken, as well as to eliminate losses in their activities [2]. Forecasts are usually built using expert opinions or models (econometric methods). The forecasts concern economic and social phenomena. In enterprises, production and sales volumes are forecasted. These are operational (short-term) and strategic (medium and long-term) forecasts. In the forecasting process, statistical (empirical) data used to build forecasts are important (assumed to be up-to-date, reliable, complete, comparable) [3-6]. The content of this work is the methodology for forecasting the volume of steel production for Poland. The forecasts for steel production in total and broken down into applied steel production technologies (BOF converter process and EAF electrical process) were made. The work was based on the statistics of the World Steel Association [7] and Polish Steel Association in Katowice [8]. Statistical data related to the volume of steel production in Poland in the years 2000-2015. The production volume was given in millions of tons of crude steel produced in a given year. In Poland, two production technologies are used: BOF and EAF. Steel melting in the Marten furnaces was completed in 2002 [9]. The size of produced steel in this technology in the first two years of research (2000-2001) was so small (its share in annual production was adequate in 2000 - 3.8 %; in 2001 - 2.3 %, in 2002 - 1.2 %), that it was not included in the research. The forecasting methodology applied by the author was based on the total volume of steel production coming from two processes: BOF and EAF [9-11]. The original methodology of forecasting is innovative due to the variant used to predict changes in the volume of steel production.

2. THE CONSTRUCTION OF THE FORECASTING MODEL

The construction of the model proposed by the author was two-pronged. **STEP I** (stage 1) consisted in building separate forecasts of total steel production and steel production in the converter process (BOF) and steel production in the electrical process (EAF). **STEP II** (stage 2) uses the principle of differences according to which the total steel production minus steel production produced in oxygen converters is the production of steel produced in electric arc furnaces and vice versa the total steel production minus steel production generated in arc furnaces is the steel production in converters (both productions constitute combined production in the steel sector). **STEP II** consisted of the **A Variant**, which built the forecast for steel production in converters (BOF) and estimated forecasts for the production of steel produced in electric arc furnaces (EAF) and **Variant B** involving the construction of forecasts for the production of steel produced technology EAF and assessing the prospects for production of steel produced by BOF technology. The methodology according to stage 1 was the basic methodology, and according to step 2 it was the supplementary methodology (supplementary). The application of stage 2 allowed the author to compare the obtained forecasts and establish acceptable forecasts, worth recommending for using them by metallurgical enterprises when making decisions. The segments of the forecasting model are presented in **Figure 1**.

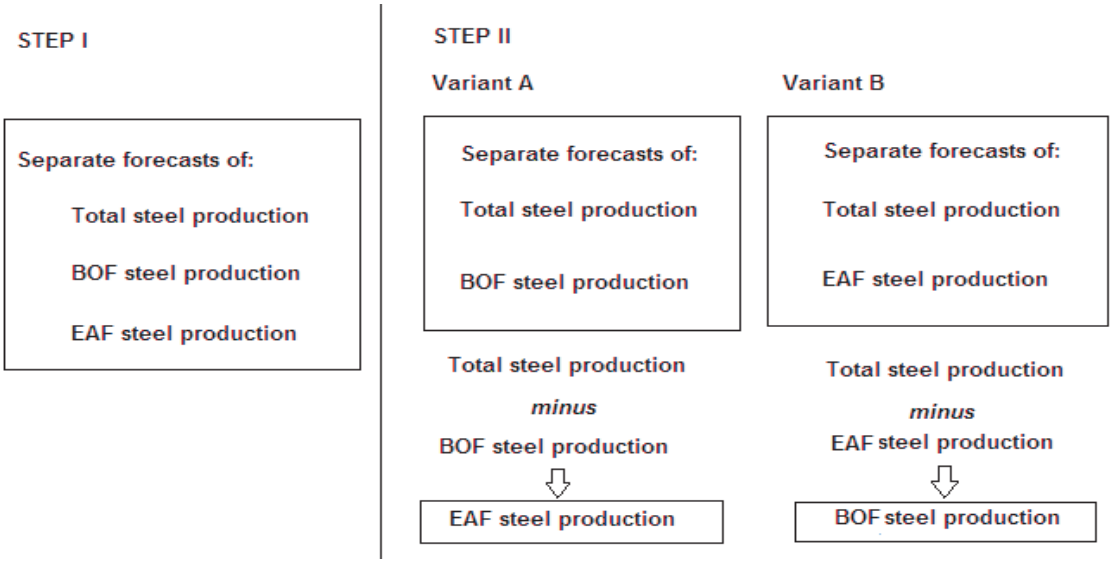


Figure 1 The segments of the forecasting model for steel production in Poland
Source: Own research

Forecasting began from 2016 and finished in 2020. All forecasts were based on empirical data for the years 2000-2015 (statistical data used for forecasting are presented in **Table 1**). Statistical data on the volume of steel production in Poland in 2016-2017 were provided for comparative purposes (during forecasting, these data were not published) and after obtaining forecasts they were used to calculate forecast errors - ex post).

Table 1 Steel production in Poland in 2000-2015

Year	Total steel production	BOF steel		EAF steel	
	mln tons	mln tons	% *	mln tons	% *
2000	10.498	6.800	64.7	3.285	31.3
2001	8.809	5.823	66.1	2.809	31.9
2002	8.367	5.799	69.3	2.561	30.7
2003	9.107	6.070	66.6	3.037	33.4

Table 1 Continue

Year	Total steel production	BOF steel		EAF steel	
	mln tons	mln tons	% *	mln tons	% *
2004	10.578	6.858	64.8	3.721	35.2
2005	8.336	4.893	58.7	3.443	41.3
2006	9.992	5.766	57.7	4.225	42.3
2007	10.631	6.198	58.3	4.433	41.7
2008	9.727	5.225	53.7	4.502	46.3
2009	7.128	3.236	45.4	3.893	54.6
2010	7.993	3.995	49.9	3.998	50.1
2011	8.776	4.424	50.4	4.353	49.6
2012	8.348	4.227	50.6	4.132	49.4
2013	7.950	4.399	55.3	3.551	44.7
2014	8.558	5.067	59.2	3.491	40.8
2015	9.202	5.323	57.8	3.879	42.2
2016	8.999	5.100	57.0	3.900	43.0
2017**	10.333	6.200	60.0	5.167	40.0

* % in total steel production. ** data unpublished up to now.

Source: own reserach on the basis of reports publised by Polish Steel Association.

Forecasts were built using econometric models (linear and linearized functions), adaptive and autoregressive models. The optimization of the point forecast value was based on the search for the minimum value of one of the errors: *RMSE* - root-mean-square error* (formula 1) and Ψ - the average value of the relative error of ex-post forecasts (formula 2), treated as the optimization criterion.

$$RMSE^* = \sqrt{\frac{1}{n-m}\sum_{t=m+1}^{n}\left(y_t - y_t^*\right)^2} \tag{1}$$

$$\Psi = \frac{1}{n-m}\sum_{t=m+1}^{n}\frac{\left|y_t - y_t^*\right|}{y_t} \tag{2}$$

where:

y_t - empirical value

y^*_t - the value of the forecast

t - time (t=2000, 2001....2015)

n - number of elements of the time series (n=16)

m − number of initial periods or moments of time t, for which the expired forecast was not realized or the forecast is the effect of the start-up mechanism.

3. FORECASTS OF STEEL PRODUCTION

Taking the differences methodology (discussed in Chapter 1) and selecting the optimal forecasts that were obtained using the following methods: exponential-autoregressive model (k = 3); autoregressive model, creeping trend method - prediction based on harmonic weights obtained results presented in **Tables 2a, 2b** and **2c**.

Table 2a) Forecats of steel production in Poland in two variants: Variant A: total steel production - BOF steel production = EAF steel production, Variant B: total steel production - EAF steel production = BOF steel production (mln tons)

No.	Year	Total steel production	BOF	EAF	Forecast for total steel production Method 1	Forecast for BOF Method 2	EAF (column 5 minus column 6)	Forecast for EAF Method 2	BOF (column 5 minus column 8)
	1	2	3	4	5	6	7	8	9
1	2000	10.498	6.800	3.285					
2	2001	8.809	5.823	2.809		5.957			
3	2002	8.367	5.799	2.561		5.450			
4	2003	9.107	6.070	3.037	7.676	5.438			
5	2004	10.578	6.858	3.721	8.909	5.578			
6	2005	8.336	4.893	3.443	9.062	5.987	3.075		
7	2006	9.992	5.766	4.225	8.665	4.967	3.698	4.151	4.513
8	2007	10.631	6.198	4.433	9.001	5.421	3.581	4.544	4.457
9	2008	9.727	5.225	4.502	9.221	5.645	3.576	4.404	4.817
10	2009	7.128	3.236	3.893	9.123	5.140	3.983	4.186	4.937
11	2010	7.993	3.995	3.998	8.657	4.106	4.551	3.823	4.834
12	2011	8.776	4.424	4.353	8.736	4.501	4.235	4.139	4.596
13	2012	8.348	4.227	4.132	8.849	4.723	4.126	3.902	4.947
14	2013	7.950	4.399	3.551	8.736	4.621	4.115	3.674	5.061
15	2014	8.558	5.067	3.491	8.624	4.711	3.913	3.622	5.002
16	2015	9.202	5.323	3.879	8.702	5.057	3.644	4.011	4.691
17	**2016**				**8.817**	**5.190**	**3.627**	**4.064**	**4.753**
18	**2017**				**8.760**	**5.122**	**3.638**	**3.848**	**4.912**
19	**2018**				**8.751**	**5.086**	**3.665**	**3.822**	**4.929**
20	**2019**				**8.756**	**5.067**	**3.689**	**4.087**	**4.670**
21	**2020**				**8.756**	**5.057**	**3.699**	**4.162**	**4.594**

Marks: No. 1 Exponential-autoregressive model (k=3); No. 2 Autoregressive model (AR1)

Source: own reseach

Table 2b) Forecats of steel production in Poland in two variants: Variant A: total steel production - BOF steel production = EAF steel production, Variant B: total steel production - EAF steel production = BOF steel production (mln tons)

No.	Year	Total steel production	BOF	EAF	Forecast for total steel production Method 2a	Forecast for BOF Method 2b	EAF (column 5 minus column 6)	Forecast for EAF Method 2b	BOF (column 5 minus column 8)
	1	2	3	4	5	6	7	9	9
1	2000	10.498	6.800	3.285					
2	2001	8.809	5.823	2.809		5.957			

Table 2b) Continue

No.	Year	Total steel production	BOF	EAF	Forecast for total steel production Method 2a	Forecast for BOF Method 2b	EAF (column 5 minus column 6)	Forecast for EAF Method 2b	BOF (column 5 minus column 8)
	1	2	3	4	5	6	7	9	9
3	2002	8.367	5.799	2.561		5.450			
4	2003	9.107	6.070	3.037		5.438			
5	2004	10.578	6.858	3.721		5.578			
6	2005	8.336	4.893	3.443	8.670	5.987	2.683		
7	2006	9.992	5.766	4.225	8.591	4.967	3.624	4.151	4.439
8	2007	10.631	6.198	4.433	9.732	5.421	4.311	4.544	5.188
9	2008	9.727	5.225	4.502	9.963	5.645	4.319	4.404	5.559
10	2009	7.128	3.236	3.893	8.143	5.140	3.003	4.186	3.957
11	2010	7.993	3.995	3.998	8.792	4.106	4.685	3.823	4.969
12	2011	8.776	4.424	4.353	8.368	4.501	3.867	4.139	4.229
13	2012	8.348	4.227	4.132	8.086	4.723	3.363	3.902	4.184
14	2013	7.950	4.399	3.551	7.737	4.621	3.116	3.674	4.063
15	2014	8.558	5.067	3.491	9.299	4.711	4.588	3.622	5.677
16	2015	9.202	5.323	3.879	9.262	5.057	4.205	4.011	5.251
17	**2016**				**8.966**	**5.190**	**3.775**	**4.064**	**4.901**
18	**2017**				**9.008**	**5.122**	**3.886**	**3.848**	**5.160**
19	**2018**				**9.416**	**5.086**	**4.331**	**3.822**	**5.594**
20	**2019**				**9.407**	**5.067**	**4.340**	**4.087**	**5.321**
21	**2020**				**8.970**	**5.057**	**3.912**	**4.162**	**4.808**

Marks: No.2a. Autoregressive model AR (1,2); No.2b Autoregressive model AR (1)

Source: own reseach

Table 2c) Forecats of steel production in Poland in two variants: Variant A: total steel production - BOF steel production = EAF steel production, Variant B: total steel production - EAF steel production= BOF steel production (mln tons)

No.	Year	Total steel production	BOF	EAF	Forecast for total steel production Method 3	Forecast for BOF Method 3	EAF (column 5 minus column 6)	Forecast for EAF Method 3	BOF (column 5 minus column 8)
	1	2	3	4	5	6	7	8	9
1	2000	10.498	6.800	3.285	9.888	6.455	3.433	3.072	6.816
2	2001	8.809	5.823	2.809	8.867	5.932	2.935	2.762	6.106
3	2002	8.367	5.799	2.561	8.923	6.058	2.865	2.812	6.111
4	2003	9.107	6.070	3.037	9.123	6.107	3.016	3.026	6.097
5	2004	10.578	6.858	3.721	9.596	6.147	3.449	3.458	6.138

Table 2c) Continue

No.	Year	Total steel production	BOF	EAF	Forecast for total steel production Method 3	Forecast for BOF Method 3	EAF (column 5 minus column 6)	Forecast for EAF Method 3	BOF (column 5 minus column 8)
	1	2	3	4	5	6	7	8	9
6	2005	8.336	4.893	3.443	9.393	5.665	3.728	3.729	5.664
7	2006	9.992	5.766	4.225	9.941	5.795	4.146	4.146	5.795
8	2007	10.631	6.198	4.433	10.090	5.711	4.379	4.379	5.711
9	2008	9.727	5.225	4.502	9.347	4.993	4.354	4.354	4.993
10	2009	7.128	3.236	3.893	8.048	3.954	4.094	4.093	3.955
11	2010	7.993	3.995	3.998	7.947	3.855	4.093	4.093	3.854
12	2011	8.776	4.424	4.353	8.313	4.134	4.179	4.181	4.132
13	2012	8.348	4.227	4.132	8.367	4.344	4.023	4.028	4.339
14	2013	7.950	4.399	3.551	8.299	4.535	3.764	3.767	4.531
15	2014	8.558	5.067	3.491	8.462	4.898	3.564	3.565	4.897
16	2015	9.202	5.323	3.879	8.990	5.348	3.643	3.641	5.350
17	**2016**				**8.974**	**5.433**	**3.542**	**3.850**	**5.125**
18	**2017**				**8.958**	**5.542**	**3.416**	**3.820**	**5.138**
19	**2018**				**8.942**	**5.652**	**3.291**	**3.790**	**5.152**
20	**2019**				**8.926**	**5.761**	**3.165**	**3.761**	**5.166**
21	**2020**				**8.910**	**5.871**	**3.040**	**3.731**	**5.179**

Marks: No.3. creeping trend method - prediction based on harmonic weights

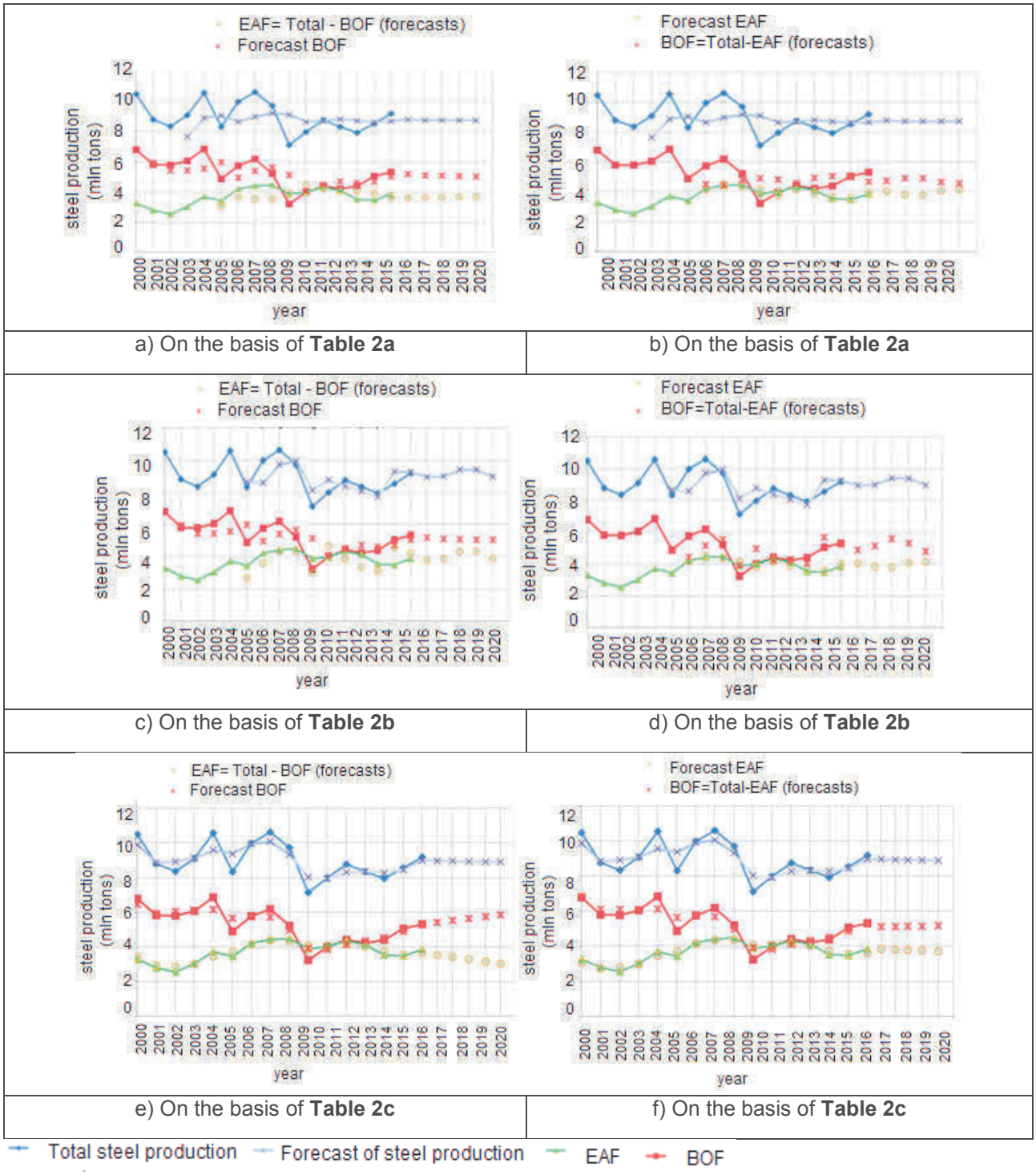
Source: own reseach

Stage II, version A obtained forecasts for BOF steel from 4.97 mln tons to 5.26 mln tons, while EAF steel from 3.7 mln ton to 4.1 mln tons (**Figures 2a, 2c, 2e**). At the stage II, version B of the forecast for BOF steel, from 4.5 mln tons to 5.3 mln tons, and for electric steel (EAF steel) from 3.6 mln tons do 4.5 mln tons (**Figures 2b, 2d, 2f**). Taking into account the current proportions between the size of produced steel in converters and electric furnaces (**Table 1**), as well as the obtained forecasts, it can be assumed that steel mills will produce more converter steel than electricity. **Table 3** presents the proportions of steel production in Poland according to BOF and EAF technology based on the obtained forecasts by author.

Table 3 Forecats of steel production in Poland according to BOF and EAF technology

Year	BOF steel (%)		EAF steel (%)	
	Version A	Forecasts	Version B	Forecasts
2016	58.5	54.8	41.5	40.9
2017	59.2	57.3	40.8	41.4
2018	59.9	59.5	40.1	40.8
2019	60.5	56.6	39.5	42.2
2020	61.2	53.6	38.8	43.2

Source: own reseach



Source: Own research

Figure 2 Variants of forecasts for steel production in Poland

4. CONCLUSION

The paper presents new methodology of forecasting of size steel production. The forecasting methodology adopted by the author 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, the partial outputs of which account for 100 %. On the basis of analysis steel sector in Poland will be produce more steel in

technology BOF (more than 50 % of total production) than steel in EAF. Steel production in Poland will be above 9 mln tons in near years.

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