FORECASTING THE CONSUMPTION OF PLATES IN PLANTS PRODUCING HEAVY PLATE CUT SHAPES

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Abstract

The paper is focused on search for suitable prediction models used for medium-term forecasting of the consumption of plates in plants producing heavy plate cut shapes. Demand time series for five product families, from the point of view of steel grade, have been assorted for this purpose. The time series include monthly demand data for the period from January 2007 to December 2009. Firstly, quantitative techniques based on time series analysis were used for the forecasting: simple moving average model with a multiplicative seasonal adjustment, Winter’s exponential smoothing model and seasonal autoregressive integrated moving average (SARIMA) model. However, the application of these models is connected with two problems. First, time series are disrupted by the world crisis impacts. Second, time series does not affect the cycle component. That is why a prediction model using multilayer artificial neural network has been created. This model includes not only the historical data regarding the cut shapes demand in the monitored period but also other factors influencing the demand for cut shapes and, consequently, the consumption of plates as well. The prediction model based on artificial neural network therefore takes into consideration the development of the situation on the steel market and the production plan of the given plant. The paper summarizes the outcomes of the created models for plates with selected product family.

Keywords: Prediction models, heavy plates, cut shapes production

1. INTRODUCTION

Plants for production of heavy plate cut shapes process hot rolled heavy plates into cut shapes – basic semi-finished products for machine parts production. The cut shapes are manufactured using the CNC controlled flame cutting machines. The flame cutting itself uses cutting technologies based on oxygen and natural gas (oxy-acetylene welder) and plasma technology. [1]

These plants use make-to-order production strategy, which determines the planning to great extent. In this strategy, there is no demand planning, because the complete production planning process starts with the entry of a sales order [2]. As the plates to be used for production of cut shapes are ordered only after the sales orders are placed, the forecasting of plate consumption is used mainly in medium-term horizon for Sales and Operations Planning (S&OP). Medium-term predictions look ahead between three months and a year – the time needed to organise the resources [3]. S&OP evaluates the anticipated sales and planned production in terms of product families. One output from this process is the production plan, which is typically stated in terms of rates of output by product family [4].

Forecasting the consumption of plates is based on predicting the demand for cut shapes. The figures acquired from prediction of demand for cut shapes are subsequently recalculated, using standards of consumption, in order to forecast the consumption of plates. Numerous techniques can be used for demand
forecasting. The common categories are time series, regression, and judgmental (qualitative techniques) [5].
Time series techniques were applied in experimental work in order to identify suitable prediction models forecasting the plate consumption.

2. EXPERIMENTAL WORK

Suitable prediction models for plate consumption forecasting have been identified in “Cut Shapes” plant in EVRAZ VÍTKOVICE STEEL a.s. company. This plant is equipped with 5 CNC controlled flame cutting machines. Hot rolled heavy plates, purely from our 3.5 m Four-High Rolling Mill production, represent the input material for cut shape production. The annual plant production capacity is currently between 29 000 and 32 000 tons (depending on assortment structure). There are two ways the prediction of plate consumption for production of cut shapes is used in this company. Firstly, it is used for material balance of “Cut shapes” plant and, secondly, for S&OP 3.5 m Four-High Rolling Mill. For the purpose, the product families are defined according to the grade of the processed plates. Five product families of cut shapes / plates are defined this way.

Time series of monthly demand of the individual product families were put together for the period from 2007 to 2009, i.e. for 36 month, so as to identify the suitable prediction models for plate consumption forecasting. Unfortunately, the data before 2007 are not available. The main reason for that is a different way of the product families’ classification.

The process of identification of suitable prediction models will be illustrated using a selected product family. The demand progress for the given product family in tons is demonstrated in figure 1. Using the time series graphic analysis, significant seasonal and, probably, also trend component can be assumed. The time series were decomposed in statistical software STATGRAPHIC Plus 5.0 in order to verify the suggested assumptions. The purpose of the decomposition is to separate demand time series into trend-cycle, seasonal, and random components. It is obvious from figure 1 that time series variability changes in time and that is why the multiplicative seasonal model was applied.

Figure 2 presents a trend-cycle component estimate by means of centered moving averages of the length of 12 months. The world crisis impact is obvious from this figure. The full extent of the crisis in metallurgical industry became evident in 2009. While the demand trend was almost constant up to 2008, in 2009, there was a sharp decrease.
Figure 3 introduces seasonal sub-series plot, which indicates seasonal component (the horizontal lines represent average value in the individual seasons for all the years in the time series, the vertical lines present the offsets between the real values and the average for each season). It becomes obvious from the figure that the highest annual demand for cut shapes from the selected product family is in April, May and June. This fact is caused by demand of those customers whose production activity strongly depends on changing seasons (for example building industry).

With regards to the occurrence of trend and seasonal component, the following adaptive and Box-Jenkins methodology models had been chosen for demand prediction:

1. Simple moving average model with a multiplicative seasonal adjustment – this model assumes that the forecast is based on unweighted average of the previous $n$ data values. The best forecast for future data is given by the average of 8 most recent data values.

2. Winter’s exponential smoothing model – this model assumes a linear trend with multiplicative seasonality estimated by exponentially weighting all previous data values. The best forecast is given by model with the following three parameters: $\alpha = 0.2776$, $\beta = 0.0324$ and $\gamma = 0.3313$.

3. Seasonal autoregressive integrated moving average (SARIMA) model - this model is based on a parametric model relating the most recent data value to previous data values and previous noise. Seasonal differences of order 1 were taken in that model. The best forecast for future data is given by SARIMA $(0,0,0)(2,1,2)c$ model.

Taking into account the relatively short demand time series, the application of models, resulting from this time series only, for creating medium-term predictions is connected with the following problems:

1. Time series are disrupted by the world crisis impacts which will make themselves felt in the following period as well.
2. Time series does not affect the cycle component, the period of which is 5.9 years in metallurgical industry [6].

That is why we searched for models which would make it possible to include not only the historical data concerning demand progress but also other factors having essential impact on prediction quality. Models using artificial neural network for forecasting comply with the above mentioned requirements. These models can be exposed to large amounts of data and discover patterns and relationships within them [7]. A multilayer perceptron neural network model described in figure 4 was designed.
The input layer consists of the following parameters:
1. Demand for the selected product family \(t\).
2. Total demand \(t\).
3. Production plan of the selected product family \(t\).
4. Production plan of the entire plant \(t\).
5. CRU Steel Price Index Global.
6. CRU Steel Price Index Flats.

The planned productions take into account the strategic targets of the plant in production area. CRU Steel Price Indexes take into account the market development (CRU is a leading independent supplier of steel market information). Time series of the described input parameters are presented in figure 5.

The model includes two hidden layers with six and five neurons and logistic activation function. With regards to the relatively short time series, the model is designed in such a way that the output is represented by the demand for the selected product family with the time horizon shifted forward by 6 month, when compared to the input data values – the model construction makes it possible to generate demand predictions for the next six months. The input data from figure 5 were divided into training, validation, and testing sets, and neural network training was performed.

3. RESEARCH RESULTS

The selection of the most suitable models was carried out mainly on the basis of Root Mean Squared Error (RMSE) and Mean Absolute Percentage Error (MAPE). Model comparison according to these statistics is presented in table 1. Medium-term prediction for 2010 is presented in figure 6.
Table 1 Models comparison

<table>
<thead>
<tr>
<th>Prediction model</th>
<th>RMSE</th>
<th>MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple moving average model</td>
<td>341.749</td>
<td>31.501</td>
</tr>
<tr>
<td>Winter’s exponential smoothing model</td>
<td>398.855</td>
<td>35.414</td>
</tr>
<tr>
<td>SARIMA model</td>
<td>5.216E-14</td>
<td>5.951E-16</td>
</tr>
<tr>
<td>Artificial neural network model</td>
<td>4.354</td>
<td>0.527</td>
</tr>
</tbody>
</table>

Table 1 makes it obvious that more suitable models for demand forecasting and, therefore, for plate consumption forecasting in the selected product family as well are SARIMA model and artificial neural network model. The remaining two models show significant prediction error (simple moving average model 31.50% and Winter’s exponential smoothing model 35.41%).

4. CONCLUSION

Considering the relatively short demand time series and medium-term prediction horizon, the selection of a single model for prediction of demand and consumption of plates in the individual product families cannot be explicitly recommended. The solution of this situation is in the use of a combined prediction acquired from the individual models. The combined prediction is a weighted average of the different predictions, with the weights reflecting in some sense the confidence the researcher has in each of the models (e.g. according to the lower RMSE) [8]. Results from some of the qualitative forecasting techniques can also be used for combined prediction.

Future research work will be focused in following directions:

- Identification of suitable models using other forecasting techniques.
- Identification of special prediction models for product families which are characterized by sporadic demand (plate consumption). The use of the suggested models for the described product families would be very problematic.
- Verification of suggested models after more demand time series are acquired.
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LITERATURE


