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ANALYSIS OF THE STATE OF PRODUCTION OF SEAMLESS STEEL TUBES AT THE SISAK STEEL WORKS

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The paper deals with the production of seamless steel tubes at the Sisak Steel Works in Sisak, Croatia since 1992, i.e. during the war and the postwar years. Due to operation at a greatly reduced capacity the steel mill and the rolling mill have faced major financial losses. Based on those negative experiences a way of overcoming the current state of affairs in steel production has been sought. The cost of specific energy consumption is analysed in respect to its share in the selling price of the product for the purpose of predicting the terms of operational profitability and reducing the financial losses caused by occasional drops in the production rate below the profit-making level.

***Key words**: steel, seamless tubes, production, profitability*

Analiza stanja u proizvodnji čeličnih bešavnih cijevi u Željezari Sisak. Prikazuje se ratno i poratno stanje od 1992. godine u proizvodnji bešavnih cijevi u Željezari Sisak. Zbog rada sa znatno manjim kapacitetom od nominalnog u čeličani i valjaonici bešavnih cijevi stvarani su znatni financijski gubici. Ta negativna iskustva poslužila su za iznalaženje načina prevladavanja postojećeg stanja u proizvodnji čelika. Analizirana je specifična potrošnja energije i njezino sudjelovanje u prodajnoj cijeni proizvoda u cilju prognoziranja rentabilnog poslovanja i stvaranja manjih financijskih gubitaka kod povremeno manje proizvodnje od rentabilne.

***Ključne riječi**: čelik, bešavne cijevi, proizvodnja, rentabilnost*

INTRODUCTION

Until 1991 at the Sisak Steel Works steel was manufactured in open-hearth and electric-arc furnace at the annual rate of about 350 000 tons. Since 1991 steel production, carried out in an out-of-date arc furnace, has been reduced to a maximum annual rate of about 70 000 tons. A slight decrease in steel production makes the cost unacceptable, in distinction from that of the steel coming from ultrahigh powered (UHP) electric furnaces [1-3].

The manufactured steel is used as the charge material at the rolling mill where the reciprocating rolling process is applied. Presently, at the mill, there are two rolling stands for large and medium size tubes. The maximum capacity of the rolling mill is close to profitable [4]. For the mill to operate profitably the steel that cannot be supplied by own steel mill has to be purchased. Since 1992 the production of seamless tubes at the rolling mill has varied from 12 000 to 56 000 tons per year inducing financial losses. The issues considered in this paper are the rate of production at the steel mill and its effect on the cost of steel, the rates of specific energy consumption at the steel mill and the rolling mill and how they affect the selling price of the mill products, and the overall financial losses at the two mills in relation to their annual production rates. In view of the negative data concerning production the price cost of steel, the rate of specific energy consumption with its share in the selling price of the product and production-related financial losses are subject of critical analysis. With the help of the parameters obtained it is possible to predict cost-efficient use of production capacities and loss-free operation, or low-loss operation at a less-than-profitable production rate.

ANALYSIS OF STEEL PRODUCTION, SEAMLESS TUBES PRODUCTION, AND SPECIFIC ENERGY CONSUMPTION WITH ITS SHARE IN THE COST OF PRODUCT

Figure 1. shows steel production (broken curve) and seamless tubes production (full curve) as well as specific energy consumption at the steel mill and the rolling mill based on annual reports on energy consumption and results

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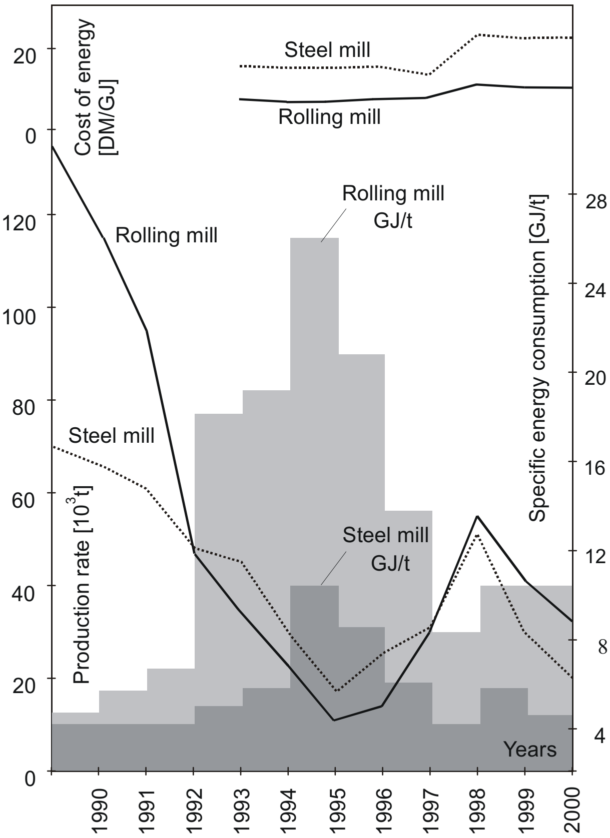

Figure 1. **Presentation of an annual steel and rolling mill production, average energy price and speciffic energy consumption in the period from1989 - 2000**

Slika 1. **Prikaz godišnje proizvodnje čeličane i valjaonice, prosječne cijene energije i specifične potrošnje energije u razdoblju 1989. - 2000.**

of work of the Sisak Steel Works [5, 6]. The costs of energy are presented by years. Those pertaining to the steel mill (broken curve) have been twice as high as the costs at the rolling mill due to a greater share of the more expensive electric power. Thanks to modern UHP furnaces the consumption of electric power as well as that of electrodes has been considerably reduced. The electric power consumption at the Sisak Steel Works, which is 650 kWh, is almost twice as high as that by modern UHP furnaces, and the electrode consumption of about 7 kg/t is about fourfold in comparison with that required by modern arc furnaces [7, 8].

With an indentical charge mass the annual production rate of UHP furnaces is considerably higher than of arc furnaces so that in conditions of decreased steel production comparable to that of the Sisak Steel Works its influence on the price cost of steel is lesser [2, 3]. Unfortunately, for profitable steel production in a UHP furnace which would meet the needs of the rolling mill, the mill capacity is too small (about 120 000 tons per year) [9, 10]. In Figure 2 an annual steel production (x) is correlated to the manufacturing price of steel on the basis of experience with the existing arc furnace. The empriric curve of regression (Figure 2., C) is defined by the equation $y = 3186.58 + 10.35x - 792.16 \ln x$ with a correlation coefficient $r = 0.9998$. Only a production rate close to maximum capacity can quarantee an acceptable price of steel its price on the market being around DM 560 per ton.

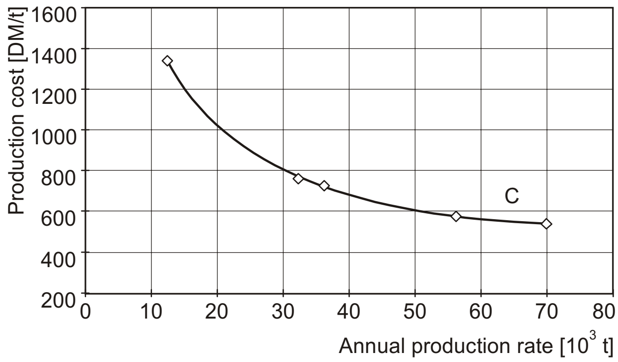

Figure 2. **Presentation of the product selling price of steel (y) correlated to an annual production (x) in the steel mill**

Slika 2. **Prikaz korelacije proizvodne cijene čelika (y) i godišnje proizvodnje (x) u čeličani**

At an annual production rate of under 30000 tons and 83% of output from the rolling mill charge, the manufacturing price of the steel charge is higher than the selling price of the tubes on the market. Correlaton of on annual production (x) and specific energy consumption (y) at the steel mill and the rolling mill and respectively of an annual pro-

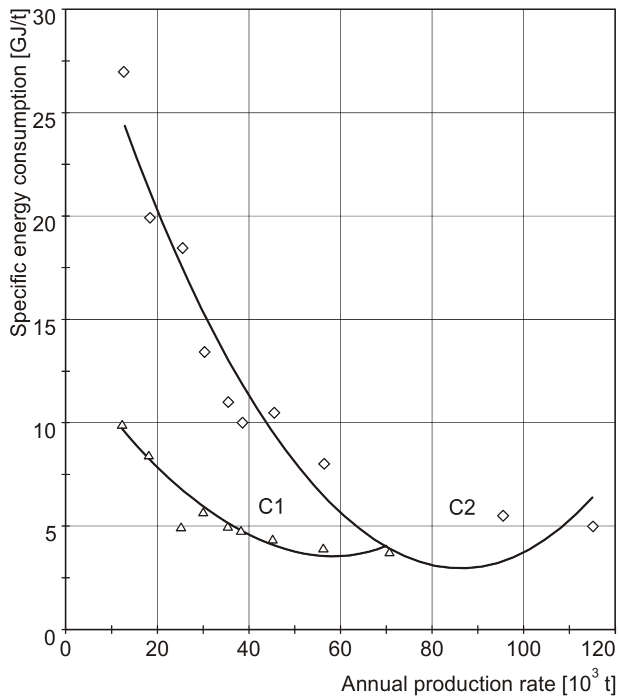

Figure 3. **Presentation of the specific energy consumption (y) correlated to an annual production (x) in the steel mill (C_1) and in the rolling mill (C_2)**

Slika 3. **Prikaz korelacije specifične potrošnje energije (y) i godišnje proizvodnje (x) u čeličani (C_1) i u valjaonici (C_2)**

duction (x) and the share of energy (consumpted in production and processing of steel) in the average selling price of the product of DM 927 per ton being the average selling price for the years 1998, 1999 and 2000 based on data from Figure 1. and presented in Figures 3. and 4.. The empiric curve of regressin (Figure 3., C_1) for the steel mill production is defined by the equation y = 13.33 - 0.342x + $0.003x^2$ with a correlation coefficient r = 0.972, and after manufacturing in the rolling mill the empiric curve of regression (Figure 3., C_2) is defined by the equation y = 31.93 - 0.676x + $0.00396x^2$ with a correlation coefficient r = 0.965. From the Figure 3. it is evident that in conditions of low annual production and former discontinued operation the rate of specific energy consumption increases several times. The share of energy cost in the average selling price of the product is illustrated in Figure 4.. The empiric curve

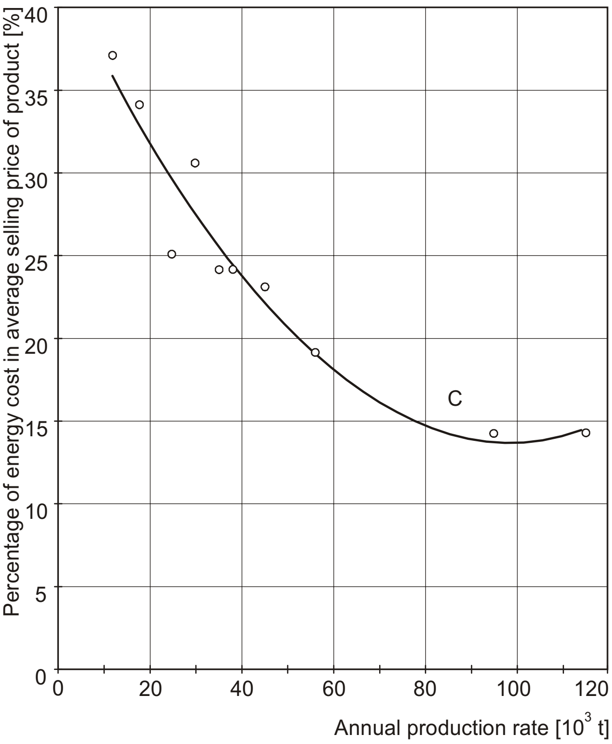

Figure 4. **Presentation of the energy share (steel and rolling mill) in a product selling price (y) correlated to an annual production of tubes (x)**

Slika 4. **Prikaz korelacije udjela energije (čeličane i valjaonice) u cijeni proizvoda (y) i godišnje proizvodnje cijevi (x)**

of regression (Figure 4., C) is defined by the equation y = 42.65 - 0.5967x + $0.00305x^2$ with a correlation coefficient r = 0.965. In the year 1995 37% of the energy cost was included in the price of product. This points at a continuous production of small quantities in conditions of disrupted production. So far common practice has been 12 hours of operation folowed by 12 hours of non-operation, with a 48-hour-standstill on Saturdays and Sundays. The heating furnaces are fuelled during the 12 and 48 hours of standstill. Inspection of the pusher-type furnaces at the Sisak Steel Works has shown that under those operating conditions the scale thickness may be up to 10 mm during prolonged downtimes [11, 12]. The same applies to the rotating-hearth furnaces for heating the charge at the rolling mill which are fuelled by the same gas and follow the same regime. As a result, the output from the steel charge is further reduced by about 2 %, or in total, 85-2% = 83%. The overall rolling mill production in the period from 1992 to 2001 (291 thousand tons of tubes in nine years) could thus have been realized in one third of the time, or in three years. The cost of energy over nine years has amounted to approximately 60 million German marks [6].

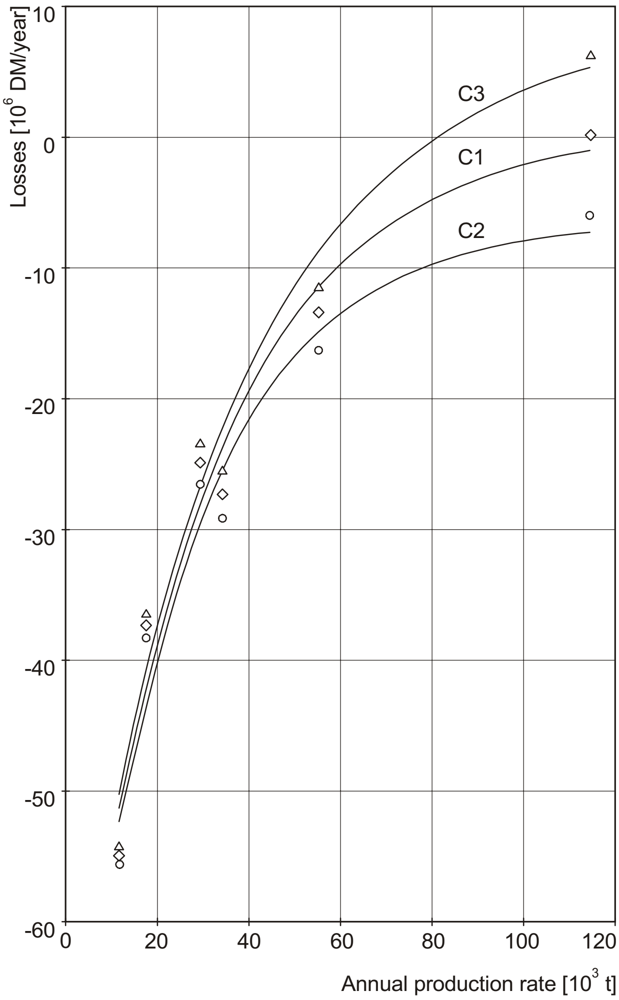

Figure 5. **Presentation of the operational losses (y) correlated to an annualproduction (x) at an average product selling price of DM 927/t (C_1), DM 872/t (C_2) and DM 981/t (C_3)**

Slika 5. **Prikaz korelacije gubitaka u poslovanju tvrtke (y) i godišnje proizvodnje (x) pri prosječnoj cijeni proizvoda 927 DEM/t (C_1), 872DEM/t (C_2) i 981 DEM/t (C_3)**

For a period of three years, with an output of 97 thousand tons of seamless tubes per year and 27 thousand tons of steel purchased, the maximum steel mill capacity being 70 thousand tons, the average specific energy consumption as shown in Figure 1. would be around 70 x 10.5 / 97 + 27 x 6.5/97 = 9.38 GJ/t. The average cost of energy for nine years is about DM 12/GJ. The cost for three years would equal about 32.8 million German marks. In nine years the energy savings would amount to approximately 27.2 million German marks. On account of a lower energy cost, a smaller amount of scale and lower other costs, a less-than-profitable production should be carried out without interruption, once a month, and then be discontinued and left at a standstill for the rest of time. This would help to decrease the operational losses. The correlation of an annual production (x) and operational losses (y) is presented in Figure 5.. The empiric curve of regression (Figure 5., C_1) for the average product selling price of DM 927/t is defined by the equation $y = 0.601 – 77.384e^{-0.0329}$ with a correlation coefficient r = 0.938, and for the average product selling price of DM 872/t the empiric curve of regression (Figure 5., C_2) is defined by the equation $y = - 6,65 - 73,04e^{-0.038x}$ with a correlation coefficient r = 0.980, whereas the empiric curve of regression (Figure 5., C_3) for the average price of DM 981/t is defined by the equation $y = 8.3 – 82.17e^{-0.028x}$ with a correlation coefficient r = 0.983. Figure 5. shows that profitable operation is possible at a production exceeding 80 thousand tons per year at the average product selling price of DM 981/t which was valid in the year 2000, and the average product selling price of DM 872/t valid in the year 1999 requires production of 120 thousand tons per year. It is evident that in circumstance of increased production the curves representing higher selling prices tend to cross the zero line (of profitable production) if capacities are small. It should be pointed out that considering the current prices and production costs the operation of the Sisak Steel Works to be profitable requires capacities that are close to maximum. Those capacities do not tolerate prolonged disruptions of production currently burdened with high costs, as the financial year cannot end with a positive balance. In contrast, rolling mills with highly profitable capacities can make up for losses even in cases of longer downtimes during the year.

CONCLUSIONS

Approximations of correlations of an annual steel and tube production and specific energy consumption as well as that of the energy share in a product selling price with theoretical function and correlation coefficients **r** were calculated using the STATISTICA program. Correlation coefficients show that correlations between the annual steel production rate on the one hand and the manufacturing cost, the cost of specific energy consumption, its share in the selling price of the product, and losses on the other are high ($0.965 \leq r \leq 0.9998$). Current analyses demonstrate that profitable production of seamless tubes is feasible if the steel mill and the rolling mill operate at maximum capacity. In that case the amount of steel up to the maximum capacity has to be purchased. Considering the current production costs, disruptions of production, if they should occur, must not be extensive, or the financial year cannot end with a positive balance. A production rate lower than the monthly profitable one calls for continuity of operation amd for its subsequent interruption to minimize losses. The results of the analysis show that the price of the product considerably influences the maximum production rate necessary for profitable operation. At a price lower than DM 872/t a profitable production rate is higher than the maximum possible production rate at the rolling mill (Figure 5., C_2). This speaks in favour of the production of seamless tubes at a selling price higher than or equal to DM 927/t in which case, with current operational costs, profitable capacity corresponds to maximum capacity (Figure 5., C_1). The selling price of DM 981/t which applied in 2000, or higher, can be taken to guarantee operational profitability (Figure 5., C_3).

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