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Statistical Model for Analysis of Lignite Used Combustion of PP "Kosova B"

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Abstract: Enormous power of blocks in PP "Kosova B" requiers knowledge of the physicochemical properties of the combustibles that are used in the combustion process inside the steam generator. The usage of this statistical model for the analysis of lignite that is used for combustion in PP "Kosova B" contributes to solving of the problems that have to do with the combustion of the lignite. The model that is used is designed to show the arrangement of the data of the consumed lignite, ash, moisture, energetic value, and the power for 24 hours. Methodology of this research is based on laboratory research and the designing of the model using Microsoft Excel. Based on the results from out observations during the analysis for the amount of lignite, ash, moisture, energetic value, and power, distribution based on normal and lognormal curve is suggested.

***Keywords**: Statistical model, simulation, lignite, normal-lognormal curve*

Introduction

Interpolation of the phenomena takes a research character when a function, that shows the distribution of the phenomenon based on the collected data, is required. A typical example of a system with discrete events is the state of lignite's parameters in PP "Kosova B" that change mostly during certain instants of time. Statistical population is a group of *N* analyses done in laboratory, for the lignite that is used for PP "Kosova B" needs, for each unit of which, the amount of one of its characteristics like: amount of lignite for 24 hours, ash, moisture, energetic value, and power is known. The model for our purpuse is based on the basic knoledge for models, results of measurements, as well as on the famous equations of the authors (Girone & Salvemini 2000; Hubler, 1996).

Materials and Methods

For the construction of statistical tables the following are taken into consideration: a) The values of statistical data of elements characteristics, such as the amount of lignite, ash, moisture, energetics value and power for 24 hours; b) Arithmetic means of classes; c) Frequencies; d) Cumulative densities; e) Cumulative frequencies; f) Relative cumulative frequencies and some other parameters. The model that is used for the construction of statistical tables is designed so that it shows the arrangement of the data for the consumed amount of energetic, ash, moisture, energetics value, and power for 24 hours, during the years 2010-2011. Using the data from the systematized and arranged measurements done in laboratory for the amount of lignite, ash, moisture, energetic value, and power, calculations of statistical variables are done with the help of special program Microsoft Excel. For the construction of statistical tables, as well as for the systematisation of the data from the results, proper model is created as follows: a). Statistical set is the set of values for the amount of lignite, ash, moisture, energetic value, and power during the 471 measurements; b). Size of the case -variable (x) is the amount of lignite, ash, moisture, energetics value, and power. First of the entire varying interval α (Girone & Salvemini 2000): where:

$$\alpha = x_{i\max} - x_{i-1\min} \tag{1}$$

Based on equation (1) classes, for statistical treatment, of lignite properties are found for the needs of PP "Kosova B". Arithmetic means of classes are as follows:

$$X_i = \frac{x_{i\max} - x_{i-1\min}}{2} \tag{2}$$

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Cumulative frequency of a modality is equal to the frequencies of modalities and to the ratio of cumulative density of this modality to the total density.

$$F_i = \sum_{a=1}^{i} f_a \ \& \ F_i = \frac{N_i}{N} \tag{3}$$

For asymmetrical statistical variables, it can be empirically verified that the values of arithmetic mean (μ), median (*Me)*, and mode (*Mo*) are related to each other based on the relations (4-5):

$$M_o \cong \mu - 3(\mu - M_e) \tag{4}$$

$$M_e = x_{\left(\frac{N+1}{2}\right)}, \ for: N-odd, and: M_e = \frac{x_{\left(\frac{N}{2}\right)} + x_{\left(\frac{N+1}{2}\right)}}{2}, \ for: N-couple \tag{5}$$

Coefficient of dispersion is give with the equation: $C_V = \frac{\sigma_x}{X}$ (6)

Table 1. Classes and densities of lignite characteristics

Number of classes	lignite, *t*/24*h*		Ash, *%*		Moisture, *%*		Energetic value, *kJ/kg*		Power, *MW*	
	x_i	n_i	x_i	n_i	x_i	n_i	x_i	n_i	x_i	n_i
1	0-300	49	4.0-6.0	9	16.0-18.0	2	4000-4500	1	200-210	1
2	300-600	64	6.0-8.0	21	18.0-20.0	10	4500-5000	13	210-220	1
3	600-900	73	8.0-10.0	16	16.0-19.0	14	5000-5500	6	220-230	13
4	900-1200	78	10.0-12.0	85	19.0-22.0	6	5500-6000	1	230-240	17
5	1200-1500	69	12.0-14.0	230	22.0-25.0	3	6000-6500	0	240-250	15
6	1500-1800	55	14.0-16.0	98	25.0-28.0	1	6500-7000	0	250-260	17
7	1800-2100	25	16.0-18.0	11	28.0-31.0	4	7000-7500	1	260-270	167
8	2100-2400	23	18.0-20.0	1	31.0-34.0	1	7500-8000	4	270-280	63
9	2400-2700	25			34.0-37.0	2	8000-8500	26	280-290	87
10	2700-3000	10			37.0-40.0	10	8500-9000	77	290-300	44
11					40.0-43.0	24	9000-9500	170	300-310	45
12					43.0-46.0	45	9500-10000	93	310-320	1
13					43.0-46.1	146	10000-10500	37		
14					43.0-46.2	176	10500-11000	14		
15					43.0-46.3	27	11000-11500	5		
16					43.0-46.4	0	11500-12000	3		
17							12000-12500	7		
18							12500-13000	0		
19							13000-13500	11		
20							13500-14000	2		
Total density *N*:		471		471		471		471		471

Results and Discussion

Comulative properties of lignite analysis are shown in Table 2. Type of the function can be chosen based on the results of the analysis for the amount of lignite, ash, moisture, energetic value, and power in 24 hours and distribution based on normal and lognormal curve (7-9) is suggested:

$$f(x) = \frac{N}{\sqrt{2\pi}} \exp\left[-(x-\mu)^2 / 2\sigma^2\right] \tag{7}$$

$$y^* = \frac{N\sigma}{\sqrt{2\pi(x-\theta)}} \exp\left\{-\frac{1}{2}[\lambda + \delta \log(x-\theta)]^2\right\} \tag{8}$$

Where: *x* is the value for the amount of lignite, ash, moisture, energetic value, and power in 24 hours. For the calculation of parameters $N, \mu, \delta, \theta, \lambda$ of normal and lognormal curve, the relation between theoretical and empirical moments is done and these results are shown in table 3:

Table 2. Cumulative properties of lignite analysis

Statistical indicators	Values for some of lignite properties				
	Amount, *t/24 hour*	**Ash [*%*]**	**Moisture [*%*]**	**Energetic value, *kJ/kg***	**Power [*MW*]**
Nr. Results	471	471	471	471	471
Maximal value	2967	18.10	45.70	13639	315
Minimal value	70	4.90	16.80	4269	206
Arithmetic mean	1161.58	12.61	39.71	9326	273
Median	1087.00	13.00	41.60	9298	270
Mode	439.00	13.30	42.00	9095	267
Standard deviation	701.19	2.17	5.88	1350	19
Variance	491666	4.70	34.53	1822402	359
Credibility	63.32	0.20	0.53	121.916	1.711
Level of credibility	0.05	1.05	2.05	3.05	3.05
Lower boundary of credibility	1098.26	12.41	39.18	9204.18	271.24
Upper boundary of credibility	1224.90	12.81	40.24	9448	275

Table 3. Parameters of interpolative curve

Parameters	Amount of lignite	Ash	Moisture	Energetic value	Power
μ	1166.66	12.61	39.77	9319.00	273.34
σ	694.84	2.21	5.92	1345.51	18.91
δ	5.92				6.89
λ	-49.16				-33.43
θ	-2918.94				143.79

After the substitutions of values for the parameters $N, \delta, \theta, and\ \lambda$ we obtain the function for the lognormal and normal curve that represent the distribution of the amount of lignite, power, ash, moisture, and energetic value using the equations (9-13):

For the amount of lignite:
$$y^* = \frac{471 \cdot 5.92}{\sqrt{2\pi}(x - 2918.94)} \exp\left\{-\frac{1}{2}\left[-49.16 + 5.92 \log(x - 2918.94)\right]^2\right\} \quad (9)$$

For power:
$$y^* = \frac{471 \cdot 6.89}{\sqrt{2\pi}(x - 143.79)} \exp\left\{-\frac{1}{2}\left[-33.43 + \delta \log(x - 143.79)\right]^2\right\} \quad (10)$$

For ash:
$$f(x) = \frac{471}{\sqrt{2\pi}} \exp\left[-(x - 12.61)^2 / 22.21^2\right] \quad (11)$$

For moisture:
$$f(x) = \frac{471}{\sqrt{2\pi}} \exp\left[-(x - 39.77)^2 / 25.92^2\right] \quad (12)$$

For energetic value:
$$f(x) = \frac{471}{\sqrt{2\pi}} \exp\left[-(x - 9319)^2 / 21345.51^2\right] \quad (13)$$

Results from the simulation for lignite analysis that is used in PP “Kosova B” are obtained also from the calculation of statistical properties like the distributions for the amount of lignite, ash, moisture, energetic value and power, and their respective interpolation curves are shown in the Figures 1-15:

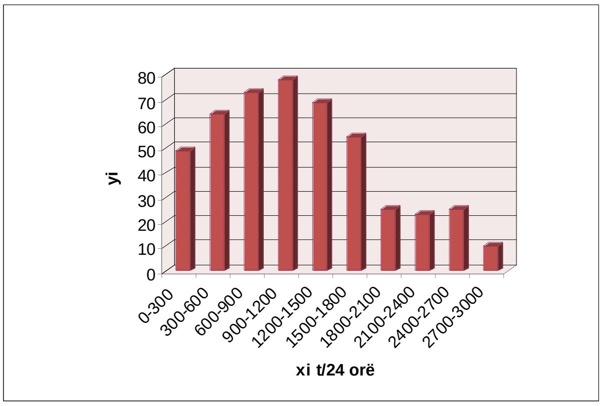

Figure 1. Distribution of total lignite mass, *t*/24*h*

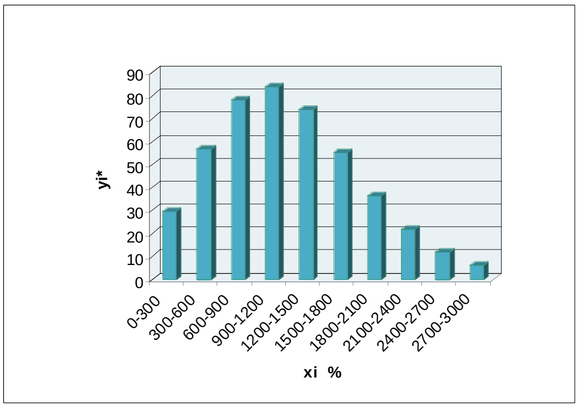

Figure 2. Approximate distribution of lignite mass

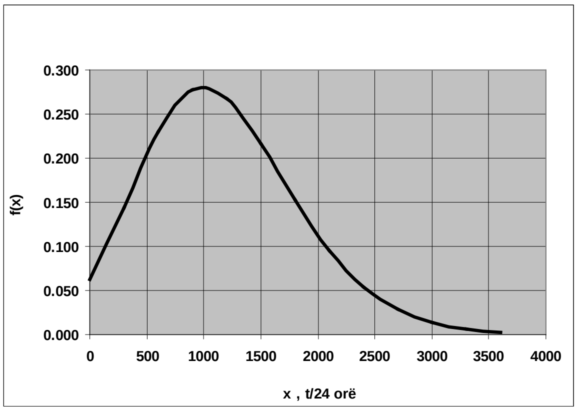

Figure 3. Interpolation curve for lignite mass

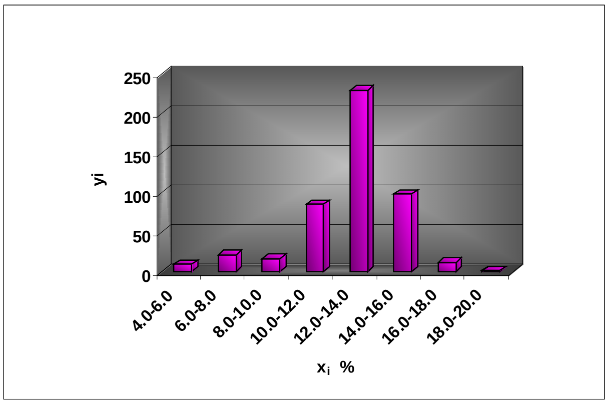

Figure 4. Distribution of ash

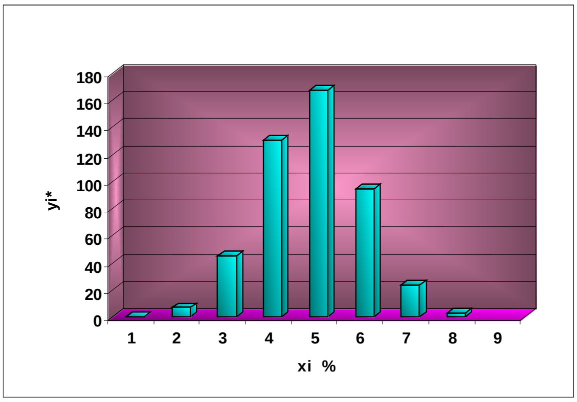

Figure 5. Approximate distribution of ash

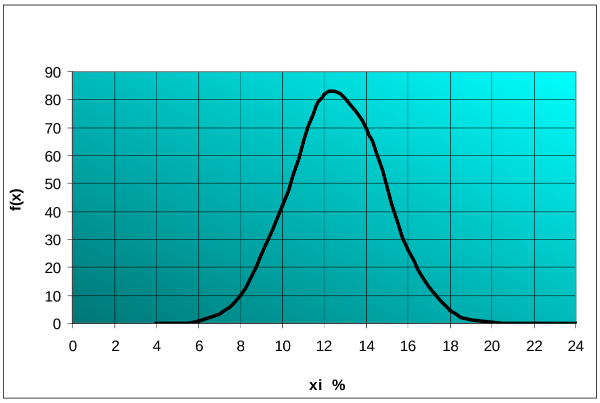

Figure 6. Interpolation curve for distribution of ash

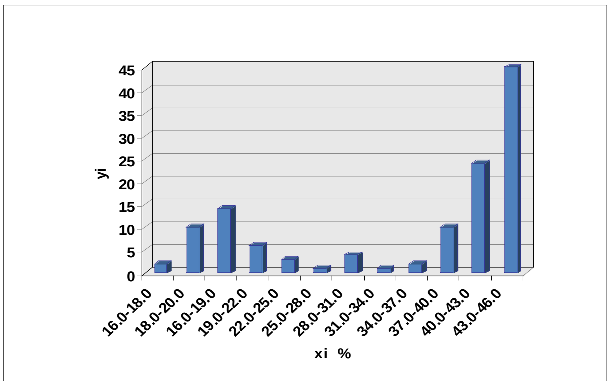

Figure 7. Distribution of moisture

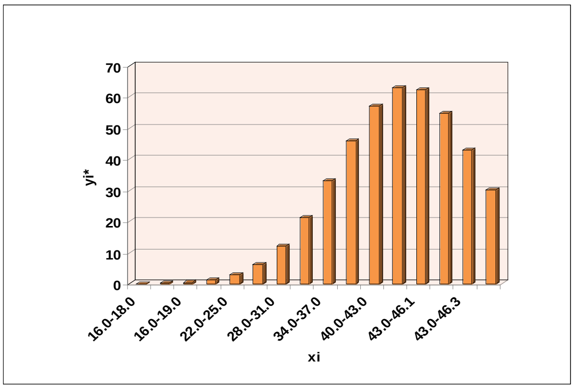

Figure 8. Approximate distribution of moisture

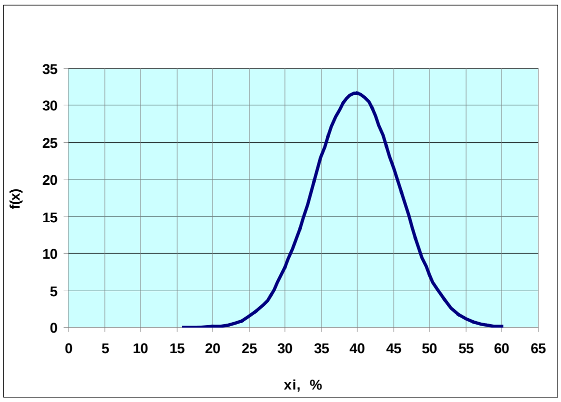

Figure. 9. Interp. curve for moisture distribution

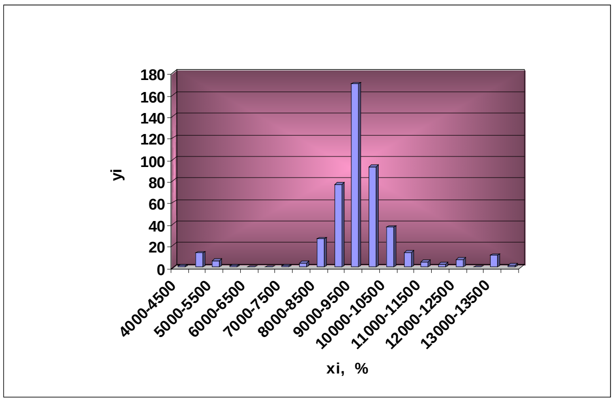

Figure. 10. Distribution of energetic value

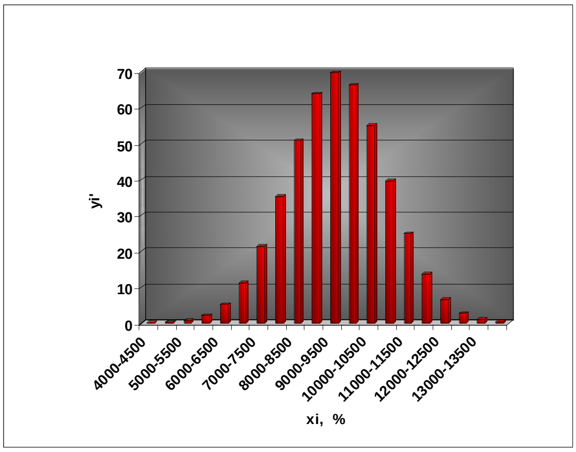

Figure 11. Approximate distribution of energy. value

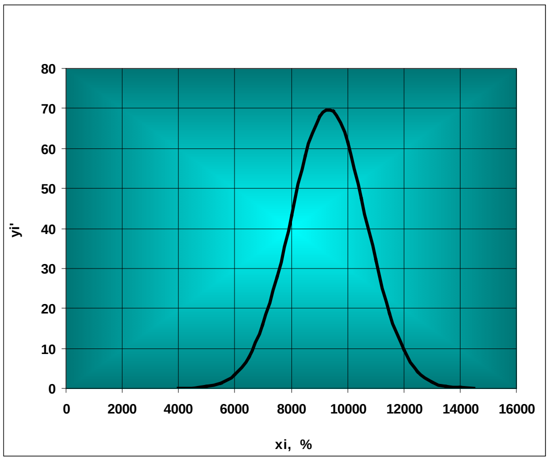

Figure 12. Interp. Curve for distribution of energy. value

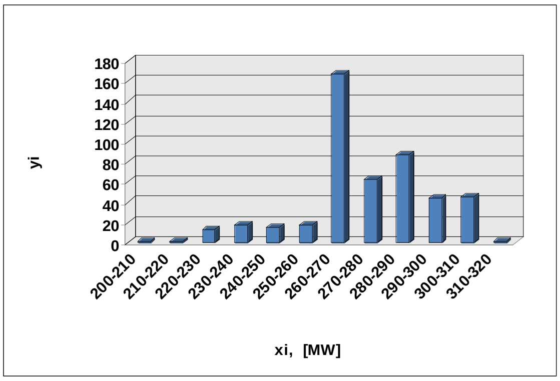

Figure 13. Distribution of power

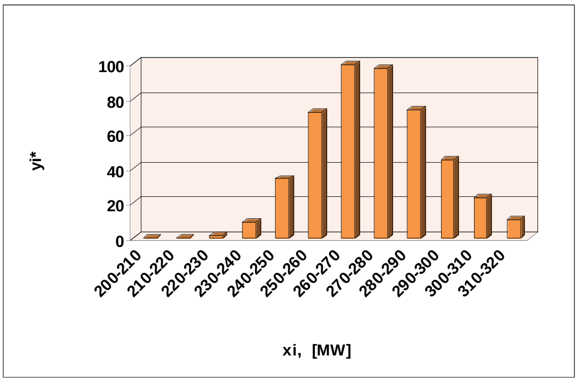

Figure 14.Approximate distribution of power

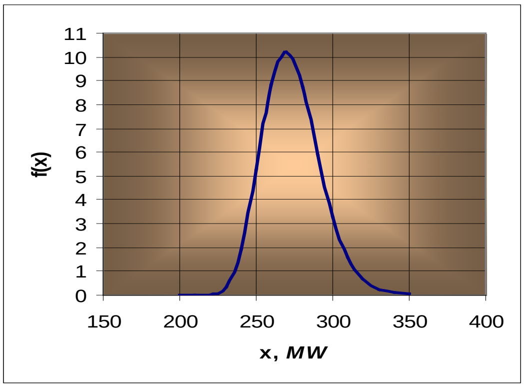

Figure 15. Interpolation curve for the distribution of power

Conclusion

Research character of normal and lognormal functions for the distribution of the analysed phenomenon during the analysis of lignite that is used in PP "Kosova B" is reached by interpolation.

Based on the results from our observations during the analysis of lignite that is used in PP "Kosova B", and other calculations we can conclude that:

- For the amount of lignite for 24 hours and power, distribution is done based on the lognormal curve.
- For the amount of ash, moisture, and energetic value, distribution is done based on normal curved.
- All the statistical indicators reach the highest values for energetic value.
- Except for the credibility level, all of the other statistical indicators have smaller values for ash.
- Level of credibility has the maximum value for the amount of lignite for 24 hours.
- From the parameters of interpolation curve, the value of arithmetic mean is the highest for energetic value whereas theoretical moment has the smallest possible value for the amount of lignite.

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