GOSPODARKA SUROWCAMI MINERALNYMI

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Coal output and unit costs of mechanical treatment of particular coal grades

Introduction

In coal mining the unit cost of coal offered for sale is typically expressed as the sum of costs involved per an average tonne of commercial coal. If mining companies should make an effort to improve their financial performance, the unit production costs of coal from various panels have to be monitored on a regular basis. It is reasonable to suppose that that differences in unit costs involved in coal production from various faces within the same colliery might be so considerable, so that coal mining activities might be abandoned at some regions, at least until the production costs- coal price relationship becomes more favourable. Despite some natural obstacles encountered in some mines, which at least partly justify higher costs, usually the potentials of costs reduction are not fully made use of.

The need to do more or less precise calculations of production costs at each stage meets with full understanding in most mines whilst computing the unit cost of mechanical treatment of particular coal grades still receives little attention. The mined coal often contains such amounts of dirt that its parameters are much lower and hence is difficult to sell. After winning, this coal has to pass to the mechanical treatment plant where it is sorted (or homogenised in terms of its grain size) and cleaned to remove the contaminants, to improve its calorific value and the ash content so that they should meet the customer's demands. This can be achieved by handling the graded coal in a number of dressing processes and the costs of mechanical treatment of particular grades might differ considerably. One has to bear in mind that the prices of particular coal grades are different, too. When considering coal grades

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with comparable calorific value, the general rule is that the coarser coal grade, the higher price.

The major consumers of coal in Poland are electric power plants and municipal heat and the power sector who tend to prefer fine coal grades, differing in their calorific value and ash content to match the requirements of the hearth or fluidised- bed installations. The admissible range of sulphur content in coal depends on whether the customer has provided a sulphur--removal installation. Mining companies are often faced with the fact that the demand for coarse and medium grades runs short of the supply and hence it seems expendable to crush certain amounts of larger-size grades despite their higher price. Fine coal obtained during crushing is typically mixed with raw coal to form a coal blend with the required calorific value.

In special cases the information is required about production costs of particular coal grades and their price in order to select the optimal composition and proportion of the coal blend.

1. Unit costs of mechanical treatment of particular coal grades

Coal grade tables specified in the Polish technical standards having relevance to steam coal summarise about ten coal grades with the precisely defined grain size. Polish collieries typically produce selected coal grades, sometimes their amount varies over subsequent months.

In an analysed colliery the raw coal passes to the mechanical treatment plant where the stream of feed is first separated into particular grades by passing through screens with different mesh size. At that time large-size grades that are handled include: cobble, nut coal, nut coal 1, nut coal 2. Medium grades include: pea coal, or alternating pea coal and fine coal; sometimes both grades are handled at the same time. As regards fine coal, seven grades of fine coal and sludge are produced, both raw and enriched by blending with crushed coals of other grades.

The raw coal typically contains certain amounts of bare rock, which reduces its calorific value and enhances the ash content, that is why these parameters have to be improved. That is achieved in the mechanical treatment plant where the separated coarse and medium grades are subjected to the enrichment process in dense media with precisely controlled specific gravity so that coal should be separated from bare rock and dirt. Fine coal grades are rarely enriched, if needs be the flotation process is selected. Calorific value of fine coal coals can be improved by blending with coal of higher calorific value, or with fine coal obtained from crushing of dressed coarse and medium grades.

As regards the calorific value, the Polish standards specify 23 classes of steam coal, ranging from 3000–7000 kcal/kg or 12.3–30.34 MJ/kg as received, the interval between the grades being 200 kcal/kg. Furthermore, there are 13 sub-classes of coal depending on the ash content while the interval between the sub-classes is 2, 3 or 5% of ash content as received. Coal mined in the analysed colliery is of good quality and hence coarse and medium grades

are produced in the calorific categories of 25, 26 and 27 MJ/kg. Considerable amounts of fine coal are available in the category 20–24 MJ/kg and 17–19 MJ/kg, there are also limited amounts of sludge in the category 12 MJ/kg.

Treatment process are most complicated, like elsewhere, which is corroborated by the data summarised in table 1, showing cost items corresponding to particular processes applied in the treatment plant. Even a brief description of the whole treatment procedure is well beyond the scope of this paper. This problem is investigated in more detail in the works by Mokrzycki (1998) and (Głodzik et al. 2009), with regards to the analysed colliery.

It is readily apparent, cost items do not cover only the treatment processes, such as crushing, classification, enrichment, thickening, dewatering of concentrate, other items include coal haulage and loading, dumping and waste rock management.

Because of the intricacy of the whole process whereby the streams of feed are directed to various processes, it is extremely difficult to clearly categorise the costs at source. That is way an alternative procedure is adopted whereby the costs are aggregated and compiled separately for each stage of the treatment installation, as shown in the table. In most cost analyses for the colliery, the costs of mechanical treatment of coal are totalled and then divided by the total amount of thus produced commercial coal. In consequence, we obtain the unit cost of mechanical treatment for an average tonne of coal. Differences between unit costs for particular coal grades are considerable, as shown in the table. It is worthwhile to mention that since particular coal grades included in the same categories (coarse or medium) are subjected to identical treatment processes, the unit costs of treatment in the given category ought to be the same.

The table summarises the costs of subsequent 21 stages in the treatment procedure over the six subsequent months. The cost items are ascribed to particular grade groups. The table specifies also the overall cost for the given stage. Division of costs of each stage into those grade groups which have passed through that stage is proportional to the mass of coal in particular grade groups. The final rows show the total costs of the mechanical treatment and the total cost broken into particular grade groups. They show also unit costs of mechanical treatment related to the overall production level and production of particular coal grades, as well as production levels in the four final rows.

It is readily apparent (see table 1 and Fig 1), the global production tends to decrease in subsequent months. The production level in November approaches only 65% of that achieved in July and then it rises again, by 26% in December. Within this time period the unit costs of mechanical treatment derived for the total production level are gradually going up, from 8.13 PLN/Mg in July to 20.14 PLN/Mg in November, which means more than 2-fold increase. Afterwards, the cost goes down in December, to 11.17 PLN/Mg, which accounts for nearly 45% decrease in relation to November. In this case we get a fairly straightforward relationship between the unit costs of treatment and production level: the higher coal production, the lower unit costs. As the observations were just few (stretching for six months only), no direct correlation can be found between the investigated quantities. Besides, in November the costs of mechanical treatment vastly increased in relation to other months

TABLE 1

Monthly costs of mechanical treatment of coal [PLN] and the unit costs of coal treatment [PLN/Mg] and production level [Mg]

TABELA 1

Zestawienie miesięcznych kosztów przeróbki mechanicznej [zł], jednostkowego kosztu wzbogacania [zł/Mg] oraz wielkości produkcji [Mg]

No.	Specification	Coal grades	VII	VIII	IX	X	XI	XII
1	2	3	4	5	6	7	8	9
1	Coal haulage and sorting	Coarse	53 047	34 401	48 872	49 550	91 675	81 033
		Medium	45 627	33 669	45 225	23 809	64 305	80 916
		Fine coal	348 178	227 805	252 161	222 515	315 003	318 656
		Total	446 852	295 874	346 258	295 874	470 983	480 605
2	Coal enrichment by hand	Coarse	4 254	42	5 554	56	48	41
		Medium	3 659	41	5 139	27	34	41
		Fine coal	0	0	0	0	0	0
		Total	7 913	83	10 693	83	83	83
3	Other sorting jobs	Coarse	4 638	9 538	5 955	13 738	20 815	14 439
		Medium	3 989	9 335	5 510	6 601	14 601	14 418
		Fine coal	30 439	63 161	30 724	61 694	71 524	56 780
		Total	39 065	82 033	42 189	82 033	106 940	85 637
4	Coal storage	Coarse	2 664	2 390	4 120	3 443	7 729	–1 261
		Medium	2 292	2 339	3 813	1 654	5 422	–1 259
		Fine coal	17 487	15 829	21 258	15 461	26 559	–4 959
		Total	22 442	20 559	29 191	20 559	39 710	–7 480
5	Coal washer- transport and handling	Coarse	85 862	64 408	27 832	86 083	176 665	105 412
		Medium	73 851	63 037	25 755	41 363	123 919	105 259
		Fine coal	0	0	0	0	0	0
		Total	159 713	127 446	53 587	127 446	300 584	210 671
6	Coal washer-enrichment of coarse coal and pea coal	Coarse	188 195	181 822	126 076	243 008	291 573	159 020
		Medium	161 869	177 951	116 669	116 765	204 521	158 790
		Fine coal	0	0	0	0	0	0
		Total	350 063	359 773	242 745	359 773	496 094	317 810
7	Washer operator	Coarse	52 376	46 704	41 861	62 421	87 048	55 296
		Medium	45 050	45 710	38 738	29 993	61 059	55 215
		Fine coal	0	0	0	0	0	0
		Total	97 426	92 414	80 599	92 414	148 107	110 511
8	Coal washer-other tasks	Coarse	9 135	12 183	9 696	16 283	24 236	14 840
		Medium	7 857	11 923	8 972	7 824	17 000	14 819
		Fine coal	0	0	0	0	0	0
		Total	16 992	24 106	18 668	24 106	41 236	29 659
9	Systems of water-slime circuit	Coarse	77 114	59 823	72 032	79 955	65 530	76 707
		Medium	66 327	58 549	66 657	38 418	45 965	76 596
		Fine coal	0	0	0	0	0	0
		Total	143 442	118 372	138 689	118 372	111 495	153 303
10	Sedimentation tanks and ponds	Coarse	7 233	6 180	8 588	8 259	10 170	5 115
		Medium	6 221	6 048	7 947	3 969	7 133	5 108
		Fine coal	0	0	0	0	0	0
		Total	13 453	12 228	16 535	12 228	17 303	10 223
11	Flocculation process	Coarse	103	97	99	129	112	96
		Medium	88	95	92	62	79	96
		Fine coal	0	0	0	0	0	0
		Total	191	191	191	191	191	191
12	Coal loading onto coal wagons	Coarse	24 355	26 505	27 058	38 177	39 117	78 747
		Medium	20 948	25 940	25 039	18 344	27 439	78 633
		Fine coal	159 854	175 515	139 608	171 439	134 411	309 666
		Total	205 157	227 960	191 704	227 960	200 967	467 046

TABLE 1. cont.

TABELA 1. cd.

1	2	3	4	5	6	7	8	9
13	Enrichment in other washers	Coarse	0	0	0	0	0	0
		Medium	0	0	0	0	0	0
		Fine coal	0	0	0	0	680 453	55 686
		Total					680 453	55 686
14	Coal dumping on the stockpiles	Coarse	14 116	0	0	0	5 062	27 358
		Medium	0	0	0	0	0	0
		Fine coal	236 291	223 531	184 014	223 531	119 057	151 724
		Total	223 531	184 014	223 531	124 119	179 082	
15	Collecting coal from the stockpiles	Coarse	502	0	0	0	866	16 369
		Medium	0	0	0	0	0	0
		Fine coal	8 395	12 518	12 381	12 518	20 373	90 784
		Total	8 896	12 518	12 381	12 518	21 239	107 153
16	Maintenance of stockpiles	Coarse	4	0	0	0	3	12
		Medium	0	0	0	0	0	0
		Fine coal	73	78	78	78	74	66
		Total	78	78	78	78	78	78
17	Coal transport to the colliery's own sites	Coarse	73	0	0	0	47	127
		Medium	0	0	0	0	0	0
		Fine coal	1 230	2 079	2 529	2 079	1 109	702
		Total	1 304	2 079	2 529	2 079	1 156	828
18	Team of workers responsible for mechanical treatment	Coarse	42 990	38 328	59 529	55 207	119 645	69 447
		Medium	36 976	37 512	55 087	26 527	83 924	69 346
		Fine coal	282 165	253 809	307 148	247 915	411 108	273 094
		Total	362 130	329 649	421 764	329 649	614 677	411 887
19	Loading and handling of rock	Coarse	3 188	2 997	3 080	4 006	3 486	–4 996
		Medium	2 742	2 933	2 850	1 925	2 445	–4 988
		Fine coal	0	0	0	0	0	0
		Total	5 930	5 930	5 930	5 930	5 930	–9 984
20	Transport of rock	Coarse	243 432	40 854	186 204	54 602	417 061	171 610
		Medium	209 379	39 984	172 311	26 236	292 542	171 361
		Fine coal	0	0	0	0	0	0
		Total	452 812	80 839	358 516	80 839	709 603	342 970
21	Supervision of mechanical treatment- costs of personnel	Coarse	13 252	14 461	19 585	20 830	27 009	18 693
		Medium	11 398	14 153	18 124	10 009	18 945	18 666
		Fine coal	86 979	95 763	101 052	93 540	92 806	73 508
		Total	111 628	124 378	138 760	124 378	138 760	110 867
22	Total costs of mechanical treatment (items 1–21)	Coarse	826 533	540 732	646 140	735 746	1 387 898	888 106
		Medium	698 272	529 221	597 930	353 523	969 332	843 015
		Fine coal	1 171 091	1 070 087	1 050 953	1 050 770	1 872 475	1 325 707
		Total	2 695 895	2 140 040	2 295 023	2 140 039	4 229 705	3 056 827
Unit cost of coal enrichment [PLN/Mg]		Coarse	20,98	19,22	19,29	21,43	33,95	19,25
		Medium	20,61	19,22	19,29	21,43	33,81	18,30
		Fine coal	4,53	5,74	6,08	6,82	13,33	7,31
		Total	8,13	8,84	9,67	10,44	20,14	11,17
Production level [Mg]		Coarse	39 389	28 137	33 493	34 327	40 876	46 130
		Medium	33 879	27 538	30 993	16 494	28 672	46 064
		Fine coal	258 532	186 325	172 812	154 152	140 453	181 406
		Total	331 800	242 000	237 298	204 973	210 001	273 600

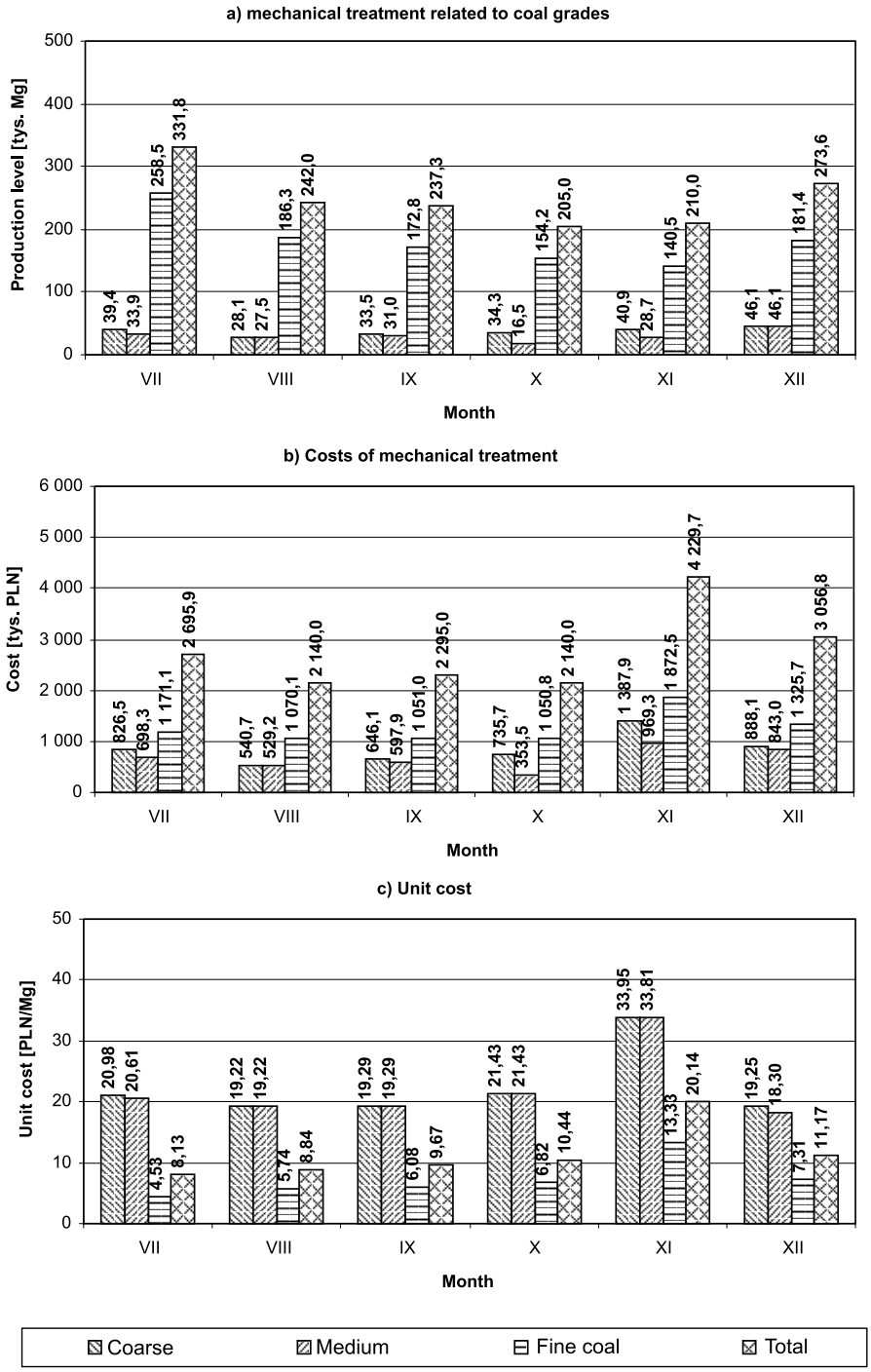

Fig. 1. Production level, global and unit costs of mechanical treatment

Rys. 1. Produkcja, koszty globalne i jednostkowe przeróbki mechanicznej

due to coal washing and fine coal enrichment in the outside firm , other costs included the costs of maintenance team and rock handling and transport.

As regards coarse and medium grades, the production level seems to increase and then decrease. For coarse grades, the minimum level is reached in September (33 493 Mg) and the maximum level is registered in December (46 130 Mg). For medium grades, the minimum level is reached in October (16 494 Mg) and the maximum in December (46 064 Mg). Hence the statement that the increase in production level brings about an decrease of unit costs does not seem to apply, though for medium grades at the peak level in December the unit costs is actually the lowest approaching 18.30 PLN/Mg. For coarse grades, the unit in December is similar to the minimal one, amounting to 19.25 PLN/Mg (the minimum level registered in August is 19.22 PLN/Mg). The highest unit costs for the two grade groups are registered in November: 33.95 PLN/Mg for coarse grades and 33.81 PLN/Mg for medium grades. Such high unit costs in November might be partly attributable to the causes mentioned before (coal washing, enrichment in the outside firm, repairs and transport of rock).

It is readily apparent (see table 1) that the amount of fine coal, like the total production level, reaches its peak in July (258 532 Mg) and gradually goes down to 140 453 Mg in November (54% of the level registered in July). It then slightly increases in December (to 70% of the level reported in July). As the amounts of this grade of coal decrease in subsequent months, the unit costs of mechanical treatment tend to increase (from 4.53 PLN/Mg in July to 13.33 PLN/Mg in November). That means that reducing the production level by half causes a nearly 3-fold increase in the unit costs of mechanical treatment. Increase in the production level is accompanied by the reduction of unit cost to 7.31 PLN/Mg. For this grade group, the relationship between the production level and unit costs seems fairly straightforward.

Summary

In a relatively short period of time (six months) we are still able to identify the relationship between the total production level, production levels of selected coal grades and the unit cost of coal production. As the production level increases, the unit cost of mechanical treatment tends to decrease, though it does not apply to coarse and medium grades in the analysed colliery. This may be so because the number of analysed samples is too small or the proportion of these coal grades in the total production numbers might be too low.

The table above reveals major fluctuations of unit costs of mechanical treatment. As regards the total production levels, the difference between the lowest and highest cost is more than 2-fold, and in the group of fine coals the registered difference is nearly 3-fold. In the group of coarse and medium grades this difference is slightly smaller, less than 2-fold, the exact factors being 1.78 and 1.84.

There are also major differences between unit costs of treatment between particular coal grades and the total production level. Unit costs of mechanical treatment for fine coals

approach 60% of the level registered for the total production (from the minimum 55.7 to maximum 66.1%). Unit costs for medium grades are 1,63 to 2.53 times higher that for the total production. Unit costs of treatment of coarse grades are 1.68–2.58 times higher than for the total production.

These observations may suggest a certain oversimplification of the problem when considering the average cost of mechanical treatment for the whole coal production. Bearing in mind that price differences between particular grades are considerable, too, mining companies have to know the price and costs of production of particular coal grades to effectively control their financial performance.

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COAL OUTPUT AND UNIT COSTS OF MECHANICAL TREATMENT OF PARTICULAR COAL GRADES

Key words

Hard coal mining, costs of mechanical treatment

Abstract

This study investigates the costs control of mechanical treatment of coal in a selected Polish colliery producing steam coal. Coal production data and coal treatment costs are compiled for the period of six subsequent months. The mechanical treatment plant in the investigated colliery is capable of handling more than ten types of graded coal, differing also in their calorific value. As not all grades need to be produced each month, the compilation covers the entire grade groups: coarse, medium and fine grade, as well as the total coal output.

The analysis of costs of mechanical treatment in subsequent months and the amounts of produced coal yields the unit cost of treatment of an average tonne of coal each month. The data covering the mass of particular coal grades help us calculate the unit costs of mechanical treatment of each group of graded coal. The entire coal treatment costs each month have to be broken into particular coal grades. Nearly all grades in each group undergo identical processes (links) involved in the mechanical treatment (chain). Each subsequent link is ascribed a corresponding cost item. When more than one grade group passes through the process line, the treatment costs are divided according to the output mass of particular coal grades. If only one grade group is handled, the treatment costs are ascribed to the entire group. Summing the subsequent cost data for each grade group yields the total costs of mechanical treatment per a given grade group. Dividing by the number of tonnes of graded coal produced each month gives the unit costs of mechanical treatment for the entire group.

Calculation data are summarised in a tabular and graphic form to reveal their variability intervals and to highlight the relationship between the unit costs of coal treatment and the production level in the given grade group.

WIELKOŚĆ PRODUKCJI A JEDNOSTKOWE KOSZTY PRZERÓBKI MECHANICZNEJ SORTYMENTÓW WĘGLA

Słowa kluczowe

Górnictwo węgla kamiennego, koszty przeróbki mechanicznej, koszty jednostkowe przeróbki mechanicznej

Streszczenie

Artykuł dotyczy zagadnienia kształtowania się kosztów przeróbki mechanicznej w wybranej, polskiej kopalni węgla kamiennego wydobywającej węgiel energetyczny. Za okres kolejnych sześciu miesięcy zebrano dane dotyczące kosztów przeróbki mechanicznej oraz ilości produkowanego węgla. W badanej kopalni zakład przeróbki mechanicznej może produkować do kilkunastu gatunków węgla handlowego w różnych sortymentach i klasach opałowych. Ponieważ nie w każdym miesiącu produkowano wszystkie gatunki, dlatego w zestawieniach połączono je, uwzględniając grupy sortymentów: grubych, średnich i miałowych oraz całą produkcję łącznie.

Posiadając dane dotyczące kosztów przeróbki mechanicznej w kolejnych miesiącach oraz ilości produkowanego węgla, można obliczyć jednostkowy koszt przeróbki statystycznej tony węgla w każdym miesiącu. Z kolei dane zawierające masy produkowanych grup sortymentowych stwarzają możliwość wyliczenia jednostkowych kosztów przeróbki mechanicznej dla każdej grupy sortymentowej. Wymaga to uprzedniego rozdzielenia w każdym kolejnym miesiącu całej kwoty kosztów przeróbki na poszczególne grupy sortymentów. Praktycznie wszystkie sortymenty w każdej grupie przechodzą przez identyczne ogniwa w łańcuchu technologicznym przeróbki mechanicznej, a dla każdego kolejnego ogniwa przyporządkowane jest w kopalni odpowiednie stanowisko kosztów. O ile przez dane stanowisko przechodzi więcej niż jedna grupa sortymentowa, koszt tego stanowiska rozdziela się na poszczególne grupy proporcjonalnie do masy wychodów sortymentowych, jeśli zaś przechodzi tylko jedna grupa, cały koszt danego stanowiska przypisuje się tej grupie. Sumując kolejne pozycje stanowisk kosztów dla danej grupy sortymentowej uzyskuje się całkowity koszt przeróbki mechanicznej poniesiony na daną grupę i wobec tego po podzieleniu przez ilość ton wyprodukowanej w danym miesiącu grupy sortymentowej, uzyskuje się wielkość jednostkowego kosztu przeróbki mechanicznej dla danej grupy.

Wyliczone wielkości zestawiono w tabeli i przedstawiono w formie rysunkowej, co pozwala łatwo prześledzić ich przedziały zmienności oraz zależność kosztów jednostkowych przeróbki od wielkości produkcji danej grupy sortymentowej.