SELECTED ENGINEERING PROBLEMS
NUMBER 3
INSTITUTE OF ENGINEERING PROCESSES AUTOMATION
AND INTEGRATED MANUFACTURING SYSTEMS

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THE AUTOMATION OF MANUFACRURING COSTS ESTIMATION PROCESS

Abstract: The main aim of the research was to automate the process of manufacturing costs estimation. The repetitive stages were distinguished and the main algorithm was distinguished. Based on that algorithm the spreadsheet and computer program were developed. Finally the results were compared and conclusions presented.

1. Introduction

The product price is one of the key criteria while customer makes product search. For this reason, the manufacturer of a new technical mean must offer a product at a competitive price to meet customer requirements. Therefore the manufacturing costs estimation is extremely important stage in the constructional – designing process. Studies show that the decisions made at this stage are the key to the product cost [2, 4]. For this reason it is important to develop tools to support the process of costs estimation.

2. Algorithm

The main goal of the research was to calculate the costs of manufacturing. The costs definitions and calculation models are described in [1, 3].

Estimating the cost of production has a high repeatability of operations. The same process of calculation must be performed for each element of each size. In the case of hydraulic prop series of types, this means estimating the cost of five sizes of 11 elements so it gives a total of 55 elements. It follows that the process of manufacturing cost estimation can be automated.

The computer program was developed to improve the series of types manufacturing costs estimation process.

3. Excel spreadsheet

Most of calculations needed to estimate the cost of manufacturing has been carried out in an Excel spreadsheet. Initially, there was defined a simple array of data and relationships. During the research process the spreadsheet template was developed. Now it is possible to quickly and easily obtain the result. The spreadsheet is characterized by a specific structure. Each of step of calculation was saved in separate sheet.

The first one summarizes the design attributes. The operators used to calculate the values are marked with different colours:

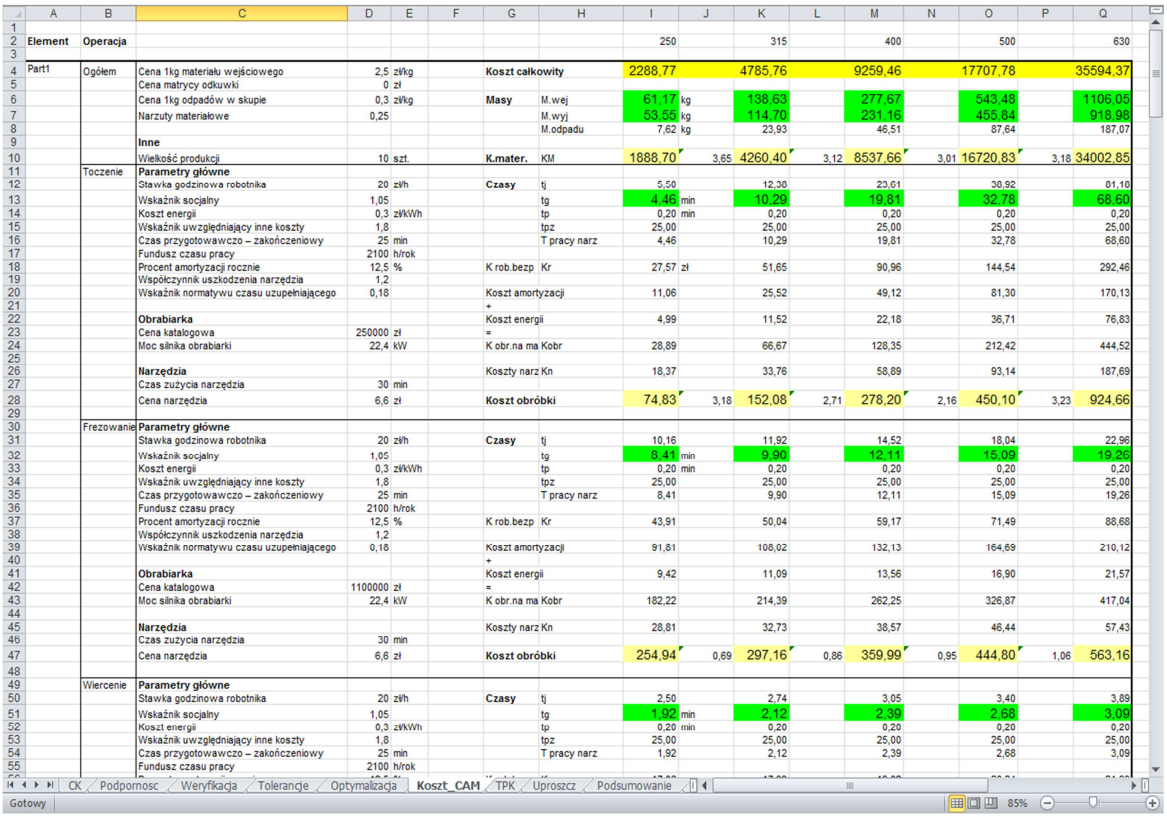
- Yellow PK - values determined under the terms of the constructional similarity,
- Red OG - values determined by geometric operators,
- Blue EK - the dimensions of the catalogue elements,
- Bronze RS - values dependent on the relationship joins,
- Orange OT - values based on technological process operators.

	A	B	C	D	E	F	G	H	I	J	K
1	PK	OG	EK	RS	OT						
2											
3			**250**		**315**		**400**		**500**		**630**
4	Part1										
5	***Name***	***Formula***	***Value***								
6	P1_1	50	50		63		80		100		125
7	P1_2	200	200	0	250	0	315	0	400	0	500
8	P1_3	20	20		25		32		40		50
9	P1_4	100	100		160		200		250		315
10	P1_5	80	80		100		125		160		200
11	P1_6	32	32		40		50		63		80
12	P1_7	63	63		80		100		125		160
13	P1_8	5	5		6,3		8		10		12
14	P1_9	2	2		2,5		3,2		4		5
15	P1_10	3	3		3		3		3		3
16	P1_11	160	160		200		250		315		400
17	P1_12	250	250		315		400		500		630
18	P1_13	292	292		368		470		584		740
19	P1_14	9	9		12		15		18		24
20	P1_15	260	260		330		420		525		660
21	P1_16	63	63		80		100		125		160
22	P1_17	10	10		12		16		20		25
23	P1_18	P1_17	9	0	12	0	15	0	18	0	24
24	P1_19	2	2		3,2		4		5		6,3
25	P1_20	20	20		25		32		40		50
26	P1_21	25	25		32		40		50		63
27	P1_22	6,3	6,3		8		10		12		16
28	P1_23	12	12		16		20		25		32
29	P1_24	200	200		250		315		400		500
30	P1_25	(P1_13+P1_26)/2	208,5		262,25		333,75		417		526,25
31	P1_26	(P1_24-P1_28)/2+P1_	125		156,5		197,5		250		312,5
32	P1_27	5	5		5		5		5		5
33	P1_28	50	50		63		80		100		125

Fig.1. Excel spreadsheet – constructional attributes

The big advantage is the ability to define the relationship between the dimensions so user can easily determine their value and the modification are immediately taken into account.

Next sheet contains rules that, based on processing times obtained from the CAM simulation and: material prices, the rate of the worker, etc. allows to calculate the manufacturing costs of individual elements and finally of the entire series of types. With the ability to copy the cells user can freely add or delete process steps assigned to the element or add/delete elements.



Element	Operacja																				
									250		315		400		500		630				
Part1	Ogółem	Cena 1kg materiału wejściowego	2,5	zł/kg		Koszt całkowity			2288,77		4785,76		9259,46		17707,78		35594,37				
		Cena matrycy odkuwki	0	zł																	
		Cena 1kg odpadów w skupie	0,3	zł/kg		Masy	M.wej		61,17	kg	138,63		277,67		543,48		1106,05				
		Narzuty materiałowe	0,25				M.wyj		53,55	kg	114,70		231,16		455,84		918,98				
							M.odpadu		7,62	kg	23,93		46,51		87,64		187,07				
		Inne																			
		Wielkość produkcji	10	szt.		K.mater.	KM		1888,70	3,65	4260,40	3,12	8537,66	3,01	16720,83	3,18	34002,85				
	Toczenie	Parametry główne																			
		Stawka godzinowa robotnika	20	zł/h		Czasy	tj		5,50		12,38		23,61		38,92		61,18				
		Wskaźnik socjalny	1,05				tg		4,46	min	10,29		19,81		32,78		68,60				
		Koszt energii	0,3	zł/kWh			tp		0,20	min	0,20		0,20		0,20		0,20				
		Wskaźnik uwzględniający inne koszty	1,8				tpz		25,00		25,00		25,00		25,00		25,00				
		Czas przygotowawczo – zakończeniowy	25	min			T pracy narz		4,46		10,29		19,81		32,78		68,60				
		Fundusz czasu pracy	2100	h/rok																	
		Procent amortyzacji rocznie	12,5	%		K rob.bezp	Kr		27,57	zł	51,65		90,96		144,54		292,46				
		Współczynnik uszkodzenia narzędzia	1,2																		
		Wskaźnik normatywu czasu uzupełniającego	0,18			Koszt amortyzacji			11,06		25,52		49,12		81,30		170,13				
						+															
		Obrabiarka				Koszt energii			4,99		11,52		22,18		36,71		76,83				
		Cena katalogowa	250000	zł		=															
		Moc silnika obrabiarki	22,4	kW		K obr.na ma	Kobr		28,89		66,67		128,35		212,42		444,52				
		Narzędzia				Koszty narz	Kn		18,37		33,76		58,89		93,14		187,69				
		Czas zużycia narzędzia	30	min																	
		Cena narzędzia	6,6	zł		Koszt obróbki			74,83	3,18	152,08	2,71	278,20	2,16	450,10	3,23	924,66				
	Frezowanie	Parametry główne																			
		Stawka godzinowa robotnika	20	zł/h		Czasy	tj		10,16		11,92		14,52		18,04		22,96				
		Wskaźnik socjalny	1,05				tg		8,41	min	9,90		12,11		15,09		19,26				
		Koszt energii	0,3	zł/kWh			tp		0,20	min	0,20		0,20		0,20		0,20				
		Wskaźnik uwzględniający inne koszty	1,8				tpz		25,00		25,00		25,00		25,00		25,00				
		Czas przygotowawczo – zakończeniowy	25	min			T pracy narz		8,41		9,90		12,11		15,09		19,26				
		Fundusz czasu pracy	2100	h/rok																	
		Procent amortyzacji rocznie	12,5	%		K rob.bezp	Kr		43,91		50,04		59,17		71,49		88,68				
		Współczynnik uszkodzenia narzędzia	1,2																		
		Wskaźnik normatywu czasu uzupełniającego	0,18			Koszt amortyzacji			91,81		108,02		132,13		164,69		210,12				
						+															
		Obrabiarka				Koszt energii			9,42		11,09		13,56		16,90		21,57				
		Cena katalogowa	1100000	zł		=															
		Moc silnika obrabiarki	22,4	kW		K obr.na ma	Kobr		182,22		214,39		262,25		326,87		417,04				
		Narzędzia				Koszty narz	Kn		28,81		32,73		38,57		46,44		57,43				
		Czas zużycia narzędzia	30	min																	
		Cena narzędzia	6,6	zł		Koszt obróbki			254,94	0,69	297,16	0,86	359,99	0,95	444,80	1,06	563,16				
	Wiercenie	Parametry główne																			
		Stawka godzinowa robotnika	20	zł/h		Czasy	tj		2,50		2,74		3,05		3,40		3,89				
		Wskaźnik socjalny	1,05				tg		1,92	min	2,12		2,39		2,68		3,09				
		Koszt energii	0,3	zł/kWh			tp		0,20	min	0,20		0,20		0,20		0,20				
		Wskaźnik uwzględniający inne koszty	1,8				tpz		25,00		25,00		25,00		25,00		25,00				
		Czas przygotowawczo – zakończeniowy	25	min			T pracy narz		1,92		2,12		2,39		2,68		3,09				
		Fundusz czasu pracy	2100	h/rok																	

Fig.2. Excel spreadsheet – CAM method

In the next spreadsheet the tables and relations were defined which allows to calculate costs witch similarity use.

Part1	Koszty wzrastające z	Koszty wzrastające z	Koszty wzrastające z		
Nr operacji	φ_1^3	φ_1^2	φ_1^1	Koszty stałe	Operacje
1.	8537,66	-	-	-	Koszty materiałowe
2.	359,99	-	-	-	Frezowanie
3.	-	278,20	-	-	Toczenie
4.	-	-	83,61	-	Wiercenie
	8897,64	278,20	83,61	0,00	9259,46
1,25	0,96	0,03	0,01	0,00	

1	-2	0,27	2499,93
2	-1	0,52	4800,53
3	0	1,00	9259,46
4	1	1,94	17917,41
5	2	3,75	34751,66

Part2	Koszty wzrastające z	Koszty wzrastające z	Koszty wzrastające z		
Nr operacji	φ_1^3	φ_1^2	φ_1^1	Koszty stałe	Operacje
1.	309,85	-	-	-	Koszty materiałowe
2.		92,59		-	Toczenie
	309,85	92,59	0,00	0,00	402,44
1,25	0,77	0,23	0,00	0,00	

1	-2	0,30	119,15
2	-1	0,54	217,90
3	0	1,00	402,44
4	1	1,86	749,85
5	2	3,50	1408,04

Fig.3. Excel spreadsheet – similarity method

Based on mass values taken from sheet shown on fig. 2 the cost are calculated with simplified method use.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
2														
3	Masy													
4	L.p.	i	Part1	Part2	Part3	Part4	Part5	Part6	Part7	Part8	Part9	Part10	Part11	Suma mas
5	1	-2	53,55	2,32	16,95	32,91	20,97	71,77	63,38	46,21	14,61	0,81	25,75	349,23
6	2	-1	114,70	4,63	34,71	65,29	39,44	142,60	124,65	88,62	28,86	1,58	45,22	690,30
7	3	0	231,16	9,40	75,75	122,02	81,81	305,40	244,05	206,88	65,32	3,16	84,41	1429,36
8	4	1	455,84	18,30	160,54	246,50	160,95	564,70	447,93	417,15	125,63	6,29	140,54	2744,37
9	5	2	918,98	36,29	346,27	453,17	320,43	1145,82	906,64	802,52	243,33	12,55	236,34	5422,34
10														
11	Stosunki mas													
12	1	-2	0,23	0,25	0,22	0,27	0,26	0,24	0,26	0,22	0,22	0,26	0,31	0,24
13	2	-1	0,50	0,49	0,46	0,54	0,48	0,47	0,51	0,43	0,44	0,50	0,54	0,48
14	3	0	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
15	4	1	1,97	1,95	2,12	2,02	1,97	1,85	1,84	2,02	1,92	1,99	1,66	1,92
16	5	2	3,98	3,86	4,57	3,71	3,92	3,75	3,71	3,88	3,73	3,97	2,80	3,79
17														
18	Koszty													
19	1	-2	2145,02	99,33	1062,66	1654,14	932,87	2923,90	3592,33	2223,80	669,52	259,91	1159,82	16723,31
20	2	-1	4594,48	198,22	2176,10	3281,63	1754,53	5809,51	7065,07	4264,73	1322,54	506,99	2036,79	33010,60
21	3	0	9259,46	402,44	4749,06	6133,02	3639,41	12441,97	13832,58	9955,85	2993,35	1013,98	3801,97	68223,09
22	4	1	18259,35	783,48	10064,87	12389,69	7160,03	23005,83	25388,35	20074,84	5757,12	2018,33	6330,17	131232,05
23	5	2	36811,10	1553,68	21709,00	22777,43	14254,67	46680,61	51387,69	38620,31	11150,83	4027,04	10645,17	259617,54

Fig.4. Excel spreadsheet – simplified method

The last book summarizes the results of all the methods presented in tabular form and on the graph.

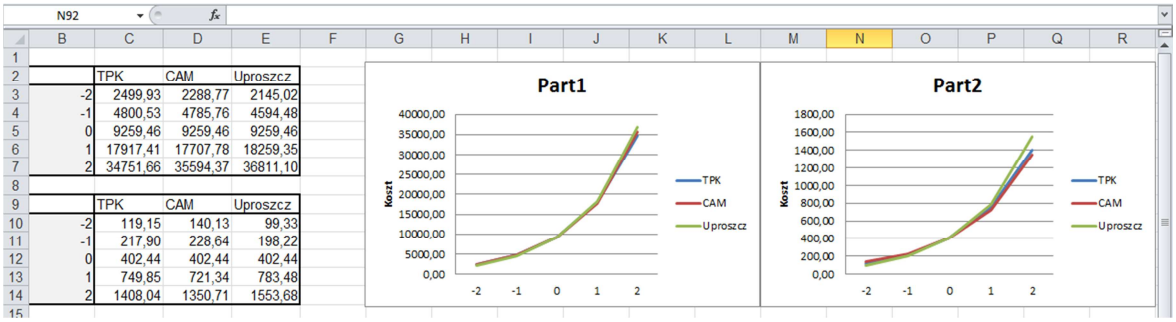


Fig.5. Excel spreadsheet – summary

Thanks to excel functionality this tool has a high versatility and flexibility.

4. Computer program

The computer program was developed. It is able to aid process of the manufacturing costs calculation. After entering the necessary data, such as the type of blank, the weight of the input and output element, the price of material and waste, the rate of the employee, etc. based on a defined manufacturing process (manufacturing – *Obróbka* tab – fig. 6) the program estimate the cost with the similarity method use, then with method based on data gathered from the CAM simulation and finally with a simplified one.

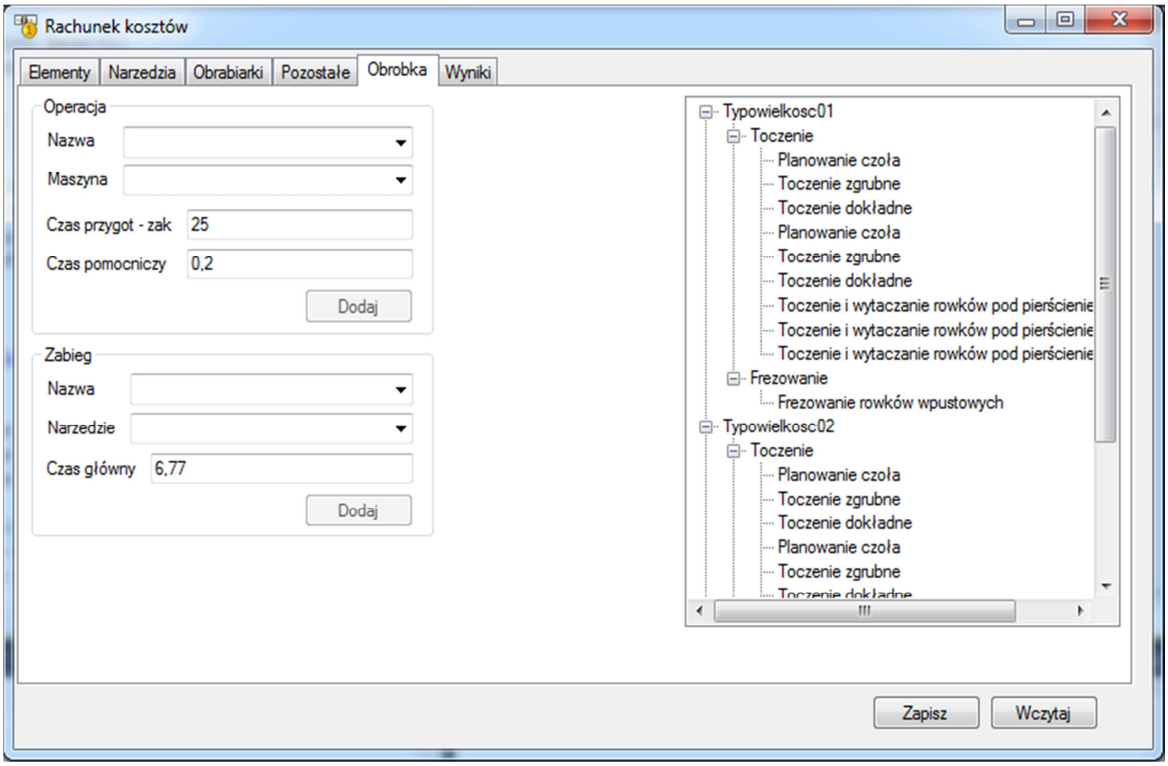


Fig.6. Program – manufacturing (Obróbka) tab

Result of the calculation is presented in a report and on the graph (fig. 7).

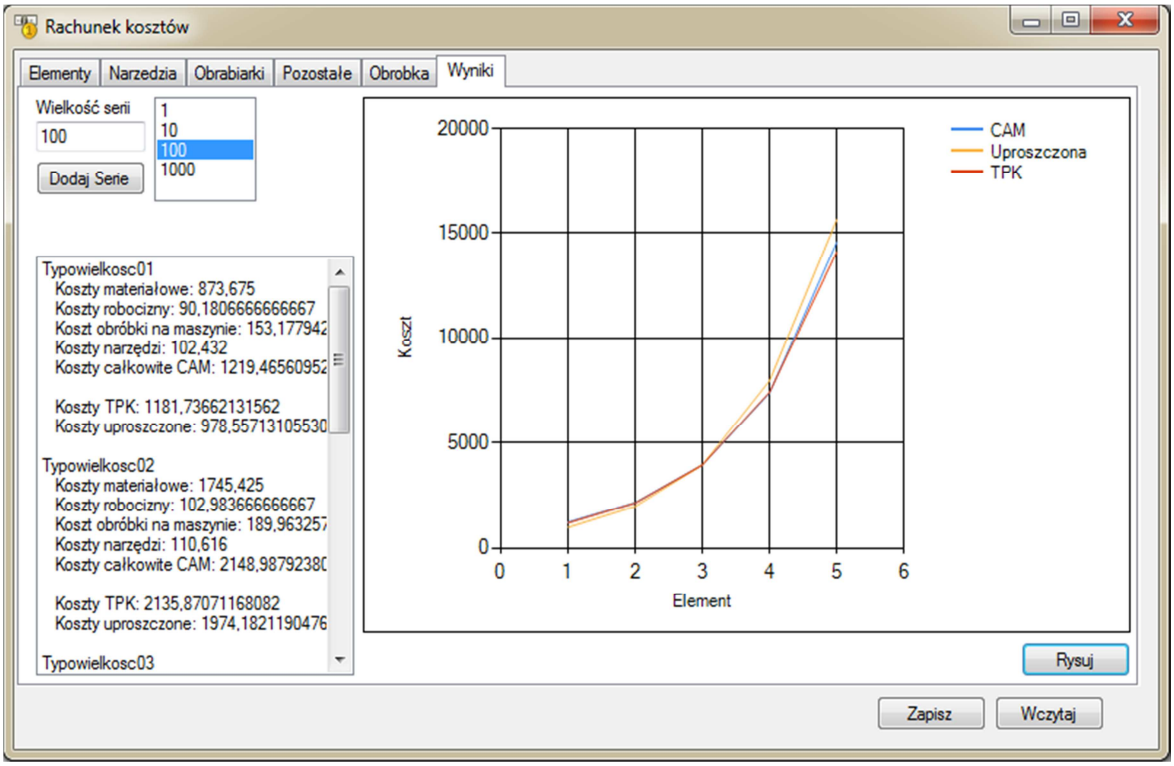


Fig.7. Result of program calculation

The results obtained by excel spreadsheet and computer program were compared. Biggest difference between that results is equal to 2,2%. The computer program and excel use different number precision. Because of that, after several mathematical operations, this small divergence increases. But still 2% difference is negligibly small.

It is possible to estimate the cost of production of an item made from various semi-finished products. In this case, in the elements tab, user should enter the same element several times with various blanks. By adding the same item several times, for which the user defines the various manufacturing processes (*Obróbka* tab) it is possible to compare the manufacturing costs of element made of different processes.

5. Conclusion

The main advantage of a spreadsheet is the fact that the results are immediately updated if a single value will be modified. In this way user can observe the results of changes and then he is able to modify the construction to minimize the costs. The spreadsheet has a high versatility and flexibility. The user can delete or modify the formula or add his own.

Sometimes, however, the possibility of any edition is undesirable and because of that the computer program was developed. This program offers a similar functionality as described sheet. This program is characterized by high versatility. It may help minimize the manufacturing costs.

Acknowledgement

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