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Neural network utilization for evaluation of the steel material properties

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Abstract: The aim of this work is to develop and test a new method for identification of material properties of the steel. This work deals with application of the small punch test for evaluation of material degradation of power station in the ČEZ company (main Czech energetic company) within the project TE01020068 “Centre of research and experimental development of reliable energy production, work package 8: Research and development of new testing methods for evaluation of material properties”. The main effort is here an improvement of empirical correlation of selected steel materials used in power industry for manufacturing of the critical components (rotors, steam-pipes, etc.). The effort here is on the utilization of the finite element method (FEM) and the neural network (NN) for evaluation of mechanical properties (Young modulus of elasticity, yield stress, tensile strength) of the selected material, based on SPT results only.

Keywords: Small Punch Test, Neural Network, Power Plant Steel, Mechanical properties

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1. Introduction

Currently, there is an effort to maximize the service life of nearly worn out operating components while maintaining the conditions for reliable and safety operation. Consequently, the new test methods for evaluation of residual service life or for determination of the actual strength values and brittle fracture properties of the exploited components are being developed. One of the methods used to evaluate the current state of mechanical properties is the small punch test (SPT) [1-4]. Such experimental method is used for both assessing the current condition of the material as well as evaluating the so-called zero states of newly manufactured power plants components.

The main aim of this paper is to create a numerical tool, which could estimate material parameters of the particular steel, on basis of already performed experiments for penetration test (SPT) and tensile test. There will not be a requirement to perform the tensile test with the currently tested material and to identify from this test these parameters. Only SPT and database of previously performed (SPT and tensile test) tests is used together with the Neural network tool. This approach can significantly reduce time and cost of the material parameters assessment.

The standard process of identifying yield stress, tensile strength is to perform tensile test and based on this test, the material properties can be evaluated [5, 6]. Moreover, fracture toughness [7] needs to be also evaluated from the individual test. However, tensile test as well as fracture toughness assessment requires large specimen of the material and it could be financially and time demanding task. The small punch test has advantage of small specimen required for the test and relatively cheap cost, but it does not allow us to directly evaluate the material properties. To ensure the safe operation of the component, it is necessary to find out the actual values of the material parameters. With the advantage of this work, one would avoid the necessity to perform an expensive tensile test. It would be sufficient to perform just a penetration test and using a suitable mathematical apparatus identified such mechanical parameters. This newly developed approach could facilitate identification of the actual material parameters of steel in a timely and economical manner.

2. Methods

A neural network (NN) was chosen as a suitable mathematical apparatus. The neural network is a computational system originally inspired by nature and the human brain. Dr. Robert Hecht-Nielsen defined the neural network as follows:

"...a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs.

In "Neural Network Primer: Part I" by Maureen Caudill, AI Expert, Feb. 1989 [8].

The original idea of the neural network was to solve the problems in a way that human brain would do. However, over time many other applications were discovered for this method. The main idea is that the network can be trained/taught using input and output data to give reasonable outputs for new inputs. The structure of the neural network is seen in Figure 1, where the first layer is the input; the last layer is the output and between them is (optional) number of the hidden layers. Each layer contains mutually connected nodes, and these are further connected to other nodes in the next layer. In this way, we get to the last layer, i.e. to the output data. However, it is necessary to properly train the network in order to create suitable connections between the layers and the nodes. There should be several hundred to several thousand input/output pairs required to properly train the network [9, 10].

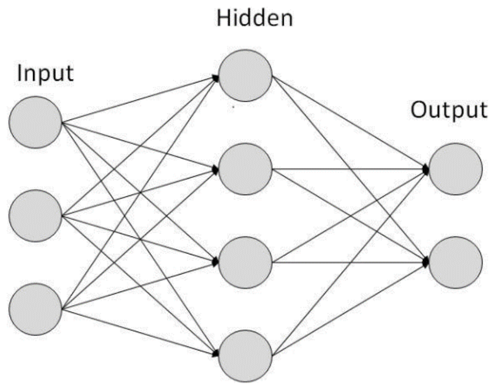

Figure 1. Structure of the neural networks.

In this case, the network would have the data from the penetration test (curve of Force versus Strain) as input and one of the following material parameters as an output: Young's modulus of elasticity E, yield stress R_{p02} and tensile strength R_m, see Figure 2. For each material value, one single network was created.

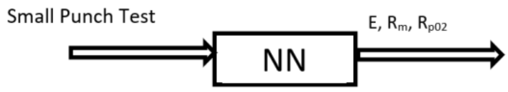

Figure 2. Diagram of the neural network based program.

The neural network has to be trained with a known data pair set (input-output). Here, experimental testing of SPT and tensile test of the given material were considered. From the standard tensile test, the material parameters were identified using standard identification method in company MATERIÁLOVÝ A METALURGICKÝ VÝZKUM, s.r.o. and directly used for the neural network as a training output. The input here was the force curve measured during SPT experiment. Consequently, the training dataset for the neural networks consist of the material parameters (E, R_{p02} and R_m) as an output and SPT curve as an input. The reference values of these material parameters come from experimental tensile test. The neural network must not only be trained, it is always necessary to test it with the use of some known pair of the input-output, which was not used in the training process. Here only one dataset of 100 specimens was available for the material 10GN2MFA. Number of 99 pairs was used for network training and one remaining pair for testing. This was done gradually with all 100 values (each of this will become ones a testing value). The final error of the neural network prediction was then evaluated. However, this process of training with the relatively small data set (100 pcs.) of only one material would predict reasonable results only for this particular material or similar one. To build a robust algorithm for prediction of any kind of material properties, one would need to build very large database of the reference specimens. Such database should contain various materials in a various state of residual life. Thus, to build the database, one must perform the SPTs as well as tensile tests, from which the reference material properties are determined. Since the database is filled up, you will only perform a SPT with the new/monitored material and the experimental curve will be used in the neural network to predict Young's modulus of elasticity, yield stress or tensile strength.

2.1 Experimental methods

In order to obtain experimental data, structural steels 10GN2MFA were used. This particular material is exploited in nuclear power engineering on a long term basis and particularly in the nuclear power engineering for power station of type VVER 1000 and MIR 1200. It was subjected to real heat treatment procedures in order to achieve real level of mechanical properties and to provide thus enough experimental data for the neural networks.

For investigated state the tensile tests was performed with subsequent determination of the curve of actual stress-strain (current state of the material), SPT or fracture toughness tests that resulted in the R curves. Since the characteristic feature of the fracture behaviour at the laboratory temperature for all of the above materials and their states after heat treatment was a stable growth of a ductile crack.

Due to the fact that both tensile and fracture toughness tests are standardized and adequately described in the literature [9,10], the next paragraph will deal only with the method of the SPT penetration tests.

The SPT method belongs to advanced testing methods developed on the long term basis in the company MATERIÁLOVÝ A METALURGICKÝ VÝZKUM, s.r.o. This method makes possible to obtain a number of mechanical properties with the use of the relatively small size of the test specimen. This method is used mainly for evaluation of the current state of mechanical properties of the components exploited in standard power engineering. In the recent past, this method was newly used also for determination of the impact of the sigma phase on the brittle fracture properties of steels used for the USC parameters [11-13].

The main advantage of the SPT method lies in the low volume of the experimental material and also in the fact that it is possible to obtain from the conducted SPT tests a number of properties. The SPT principle is illustrated in Figure 3. The test corpuscle is a disc with a diameter d_1 = 8 mm and a thickness h = 0.5 mm, which is penetrated by a hemispherical punch with a radius r = 1 mm till the failure. The diameter d_2 of the hole in the lower die is 4 mm. Record of the SPT test is shown in Figure 4. Such curve can be further used for the neural network to obtain the required values of mechanical properties [4]. In this experimental SPT, the deflection was controlled value, and thus remains very similar across the measurements and thus it was not used for the analysis.

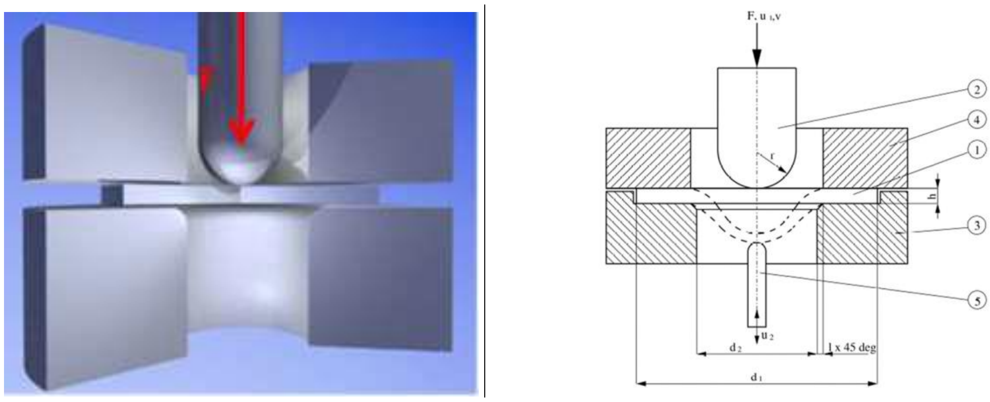

Figure 3. Principle of small punch test.

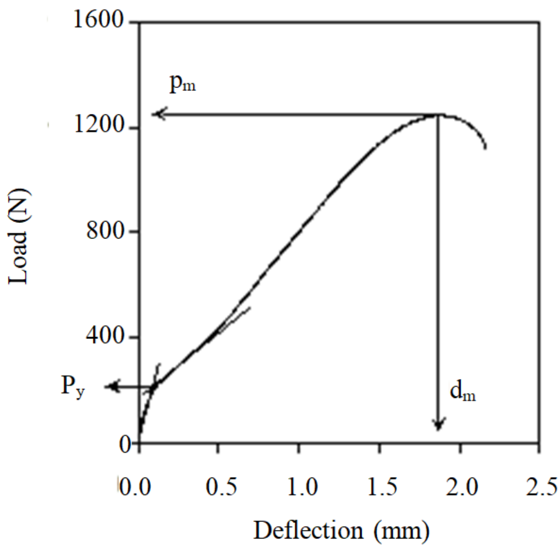

Figure 4. Record of the Small Punch Test.

3. Results

One investigated material 10GN2MFA was tested within the algorithm for evaluation of the steel material properties based on the Small Punch Test and neural network. The given 100 experimental pairs were gradually used for the training and testing of the neural network. There were always 99 pairs for the training of the network and one for the testing. The pair changes in the way, that each pair was ones a testing and 99 times a training one. The neural network provides a prediction of the material values (output) for the testing input (force vs displacement). Since these values are known (from the experiment), but not used for the training, the quality of such prediction can be assessed just with the comparison of the predicted and real values (output – E, R_{p02} and R_m). The error was calculated in absolute (MPa) and relative (%) values and the mean error was evaluated.

Table 1. Results of the Neural Network simulation of the mechanical properties.

		Mean Absolu	**Max Absolu**	**Mean Relati**	**Max. Relati**
		[MPa]		**[%]**	
10GN2MFA	E	516	45190	0.0663	20.5
	R_p	-0.09	61.6	-0.07	11.18
	R_m	0.291	51.2	-0.016	7.87

The obtained results summarised in Table 1 show good quality of the predicted values for the Young modulus of elasticity E. Maximal error of the estimation is about 20% while the mean error is less than 0.1%. Moreover, the 20% error of the prediction is still significant value. The maximal error of the predicted values for the yield stress and tensile strength is about 10%. Such estimation is considered as a good estimation, since we have only 99 training examples. For each three cases, the mean relative error is less than 0.1% and this indicates the reasonability of this approach. The complete results of the neural network (reference values, predicted values and the error is the Appendix A). Where, the name *SIM* (E_sim) refers to a simulated (predicted) value, while the *ORIG* (E_orig) refers to reference one.

4. Discussion

It follows from the obtained results summarized in Table 1, that the simulations here have good agreement with the experimental results. In our previous work started 3 year ago only limited number of data set do not exceeding 18 results was available. Such number of data set was found to be not acceptable as the scatter was too high. After improving NN methodology and increasing number of experimental data, the good agreement was found. Further work will be focused on the continuing of the experimental tests and building the material database using material like P91, P92 and A508 to get more relevant data.

5. Conclusions

The work describes the essence and the results obtained within the framework of the TAČR project TE01020068, work package 8. The project is focused on the use of the Small Punch Tests for evaluation of material degradation of critical components of conventional power plants. The aim of this work consists, in the creation of a connection between the SPT tests performed within the frame of evaluation of the actual material properties of the exploited and newly manufactured components and numerical calculation using neural networks. The first results indicate the possible application of the neural network method, especially for determining the values of mechanical properties. This work exploited the results obtained in [1], where authors tested such method on the three materials, with the maximal number of 18 values. Here, only one material, but with the larger number of specimens (100) were used. The results given here indicate/prove that the higher number of the training pairs can build better neural network with the better estimation. However there is still quite high maximal error. Moreover, the material 10GN2MFA is homogeneous material and the dispersion and quality of tested specimen was good. When the particular material would have non-linear behaviour and the scatter of the experimental data would increase, the prediction based on 100 examples only would vary significantly.

Achievement of consistent results when estimating material characteristics using neural networks would surely require a much bigger number of training samples. This is consistent with the literature, which states the need for at least several hundred or thousands pairs, for the proper functioning of the neural network. Consequently, this method would require a wide database of the experiments for each material used in the real power plants. One could not assume that building one wide database for any kind of material will bring much more reasonable results.

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References

1. Kander, L.; Špička, J. Utilization of Neural Networks for Evaluation of Material Properties of Structural Steels based on SPT Results, *Hutnické listy* č. 4/2017, ISSN 0018-8069, In press.
2. Catherine, C. S.; Messier, J.; Poussard, C.; Rosinski, S.; Foulds, J. Small punch test: EPRI-CEA finite element simulation benchmark and inverse method for the estimation of elastic plastic behaviour. In: *Small Specimen Test Techniques*: Fourth Volume. ASTM International, 2002.
3. Li, Y.; Hurst, R.; Matocha, K.; Čížek, P.; Blagoeva, D. New Approach to Determine Fracture Toughness from the Small Punch Test, In: *Metallurgical Journal*, vol. LXIII p. 94-102
4. Small Punch Test Method for Metallic Materials. CEN WORKSHOP AGREEMENT CWA 15627, December 2007
5. ČSN EN ISO 9862-1 Geosynthetics - Sampling and preparation of test specimens.
6. ASTM E 1820 Standard Test Method for Measurement of Fracture Toughness.
7. Abendroth, M.; Meinhard, K. Determination of ductile material properties by means of the small punch test and neural networks. *Advanced Engineering Materials* 6.7 (2004): 536-540.
8. "Neural Network Primer: Part I" by Maureen Caudill, AI Expert, Feb. 1989.
9. https://en.wikipedia.org/wiki/Artificial_neural_network
10. https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_neural_networks.htm
11. Kander, L.; Korčáková, L. The Influence of Sigma Phase Precipitation on Mechanical Properties of Tp347H Austenitic Steels after 100.000 Hours Service in Coal-fired Power Plant. In *Metal 2015*, Brno, Czech Republic.
12. Stejskalová, Š.; Kander, L.; Hermanová, Š. The Change of the Structure and Mechanical Properties of the Austenitic Steels after Exposure at the Critical Temperature. *In Metallography 2016*, p. 100, Stará Lesná, Slovak Republic.
13. Kander, L. Precipitation of Sigma Phase in Austenitic Steels Used in Supercritical Conditions. In *Metal 2016*, p. 103, Brno, Czech Republic.

Appendix A

E					Rp02					Rm			
E_sim	**E_orig**	**Error abs**	**Error rel [%]**		**Rp02_sim**	**Rp02_orig**	**Error abs**	**Error rel [%]**		**Rm_sim**	**Rm_orig**	**Error abs**	**Error rel [%]**
179913,2	208210	28296,81	135,905,124		507,928	526	1,807,197	3,435,736,134		6,145,796	630	1,542,037	2,447,678,383
233975,4	205032	-28943,4	-1,411,652,112		5,176,012	545	2,739,879	5,027,300,114		6,215,438	651	2,945,617	4,524,757,372
226773	206161	-20612	-9,997,987,142		4,881,569	532	4,384,307	8,241,177,815		5,943,482	635	4,065,182	6,401,861,211
190918,9	216967	26048,11	1,200,556,442		5,614,051	537	-244,051	-4,544,704,631		6,562,859	639	-172,859	-2,705,151,531
230873	204562	-26311	-1,286,213,871		5,086,515	527	1,834,851	348,168,978		6,179,982	630	1,200,183	1,905,052,805
188447,6	209460	21012,42	1,003,171,166		5,247,508	554	2,924,922	527,964,192		6,276,305	655	2,736,949	4,178,548,641
186267,3	196472	10204,7	5,193,969,254		5,271,693	527	-0,16926	-0,032117495		6,342,406	630	-424,065	-0,673118279
236676,5	207245	-29431,5	-1,420,128,505		4,822,892	543	6,071,081	111,806,272		5,942,317	645	5,076,834	787,106,123
197911	197288	-623,003	-0,315783684		5,249,188	532	7,081,153	1,331,043,847		6,317,164	635	3,283,628	0,517106831
212447,6	188409	-24038,6	-1,275,874,449		5,206,245	554	3,337,546	602,445,176		6,329,842	657	2,401,584	3,655,379,415
211581,8	201989	-9592,8	-4,749,171,487		5,165,961	524	7,403,882	1,412,954,654		6,261,159	627	0,884123	0,141008403
213250,6	209138	-4112,63	-1,966,467,337		5,350,972	525	-100,972	-1,923,266,671		633,703	628	-570,301	-0,908122105
208166,4	209269	1,102,599	0,526881222		5,064,671	529	2,253,291	4,259,530,068		6,179,101	632	1,408,994	2,229,420,477
187632,6	213394	25761,42	1,207,223,178		5,236,989	527	3,301,143	0,626402809		6,326,192	632	-0,61922	-0,097978003
180621,1	204331	23709,93	1,160,368,625		5,455,465	529	-165,465	-3,127,883,283		6,431,316	631	-121,316	-1,922,599,509
198497	211102	12605,03	5,971,062,395		5,930,581	525	-680,581	-1,296,345,527		6,873,436	627	-603,436	-9,624,177,277
211921,6	207148	-4773,59	-2,304,436,817		5,012,594	530	2,874,062	5,422,758,616		608,972	632	2,302,802	3,643,674,706
183953,5	205995	22041,53	1,070,003,125		5,596,594	526	-336,594	-6,399,117,929		6,526,686	631	-216,686	-3,434,014,915
235105,6	202846	-32259,6	-159,034,931		5,669,878	542	-249,878	-4,610,291,015		6,579,645	647	-109,645	-1,694,660,798
190593,3	207234	16640,74	8,029,926,243		5,617,689	529	-327,689	-6,194,501,745		663,534	633	-30,534	-4,823,693,537
193640,8	192917	-723,842	-0,375208961		5,433,297	524	-193,297	-3,688,882,021		6,368,811	625	-118,811	-190,097,251
210604,3	203093	-7511,33	-3,698,469,206		5,128,104	548	3,518,956	6,421,453,052		6,113,299	650	3,867,007	5,949,241,952
229383,5	213038	-16345,5	-7,672,553,218		5,602,281	547	-132,281	-2,418,307,154		6,647,267	648	-167,267	-2,581,283,666
179847,8	209388	29540,15	141,078,545		5,282,795	541	1,272,047	2,351,288,066		6,332,808	645	1,171,917	181,692,605
205263,1	198437	-6826,12	-3,439,941,019		4,895,332	524	3,446,681	6,577,636,173		5,989,544	627	2,804,557	4,472,977,972
200586,4	202338	1,751,616	0,865688034		5,739,383	525	-489,383	-932,157,434		670,62	628	-42,62	-6,786,629,048
187550	183553	-3996,99	-2,177,566,366		5,232,996	529	5,700,385	1,077,577,458		6,241,304	630	5,869,633	0,9316877
222861,9	209070	-13791,9	-6,596,799,449		5,580,009	554	-400,093	-0,72218966		6,477,652	652	4,234,814	0,64951128
196619,6	207160	10540,37	5,088,033,853		541,115	526	-15,115	-2,873,575,536		6,476,453	629	-186,453	-2,964,274,666
209494,5	193015	-16479,5	-8,537,962,062		5,417,419	522	-197,419	-3,781,979,981		6,426,773	625	-176,773	-2,828,367,997
230684	204939	-25745	-1,256,228,093		5,183,378	528	9,662,184	1,829,959,104		6,189,704	629	1,002,957	1,594,525,531
188285,6	201281	12995,45	6,456,370,613		523,655	524	0,34504	0,065847324		6,270,419	627	-0,04185	-0,006674837
208786	188583	-20203	-1,071,307,052		5,735,515	535	-385,515	-7,205,891,565		6,655,038	638	-275,038	-4,310,933,868
204809,1	218831	14021,86	6,407,620,857		5,502,414	524	-262,414	-5,007,910,041		6,398,768	624	-158,768	-2,544,357,605
231810,7	210726	-21084,7	-1,000,572,393		6,421,729	522	-120,173	-2,302,162,065		7,145,464	622	-925,464	-1,487,883,818
201111,1	231772	30660,93	1,322,891,923		5,377,606	529	-876,057	-1,656,062,461		6,445,123	631	-135,123	-2,141,405,008
218103,5	200009	-18094,5	-9,046,847,856		5,544,928	543	-114,928	-2,116,528,684		6,515,677	648	-356,773	-0,550575486
193851,7	202870	9,018,258	4,445,338,511		4,769,222	521	4,407,781	8,460,231,321		5,953,283	622	2,667,169	4,288,053,243
221342,2	200141	-21201,2	-1,059,312,437		5,280,504	530	1,949,564	0,367842194		623,605	633	9,394,966	1,484,196,782
223157,2	199641	-23516,2	-1,177,925,805		5,206,901	520	-0,69012	-0,132715715		6,262,869	621	-528,687	-0,851347633
168189,4	199786	31596,64	1,581,524,215		5,102,884	525	1,471,164	2,802,217,118		6,120,495	628	1,595,051	2,539,890,827
249630,5	204644	-44986,5	-2,198,280,451		566,358	527	-39,358	-7,468,314,975		6,584,338	628	-304,338	-484,614,422
204380,8	198889	-5491,84	-2,761,260,855		5,478,675	528	-198,675	-3,762,782,059		6,519,982	633	-189,982	-300,128,981
200119,5	202833	2,713,457	1,337,778,837		5,600,127	537	-230,127	-4,285,427,798		6,531,132	639	-141,132	-2,208,645,678
170792,7	194506	23713,32	1,219,156,473		550,379	535	-15,379	-2,874,575,951		6,498,462	639	-108,462	-1,697,375,403
254903,9	208131	-46772,9	-2,247,281,199		5,828,848	554	-288,848	-5,213,856,569		6,802,488	655	-252,488	-3,854,785,301
248400	211650	-36750	-1,736,355,382		5,369,283	523	-139,283	-2,663,155,023		6,387,111	625	-137,111	-2,193,780,184
194348,8	207607	13258,18	6,386,191,982		5,554,302	524	-314,302	-599,812,029		6,515,223	628	-235,223	-3,745,592,023
160825,5	198477	37651,49	1,897,020,131		5,124,028	525	1,259,715	2,399,457,774		6,230,338	627	3,966,191	0,632566346
180454,3	194188	13733,7	7,072,375,069		5,207,419	528	7,258,099	1,374,640,006		6,221,686	632	9,831,435	1,555,606,877
235871,6	201996	-33875,6	-1,677,042,068		5,582,566	547	-112,566	-2,057,873,314		6,562,146	649	-721,457	-1,111,643,878
232413,8	194549	-37864,8	-1,946,285,854		5,241,144	548	2,388,563	435,869,211		623,586	649	2,541,398	3,915,867,922
170588,4	205391	34802,62	1,694,456,934		5,145,674	536	2,143,263	3,998,624,254		6,220,891	637	1,491,092	2,340,803,726
192684,7	195737	3,052,293	1,559,384,809		5,422,667	542	-0,26668	-0,04920219		6,543,707	644	-103,707	-1,610,353,009
185548,5	191539	5,990,456	3,127,538,669		5,306,261	543	1,237,389	2,278,800,661		6,337,079	646	1,229,207	1,902,796,922
235466,8	188853	-46613,8	-2,468,259,102		5,626,476	530	-326,476	-6,159,923,482		654,181	630	-24,181	-3,838,259,996
176521,1	190114	13592,86	7,149,849,123		5,262,361	574	4,776,389	8,321,235,328		6,367,429	665	2,825,708	4,249,185,162
195259,9	202145	6,885,147	3,406,043,878		5,479,812	528	-199,812	-378,432,198		6,305,603	632	1,439,663	0,227794782
193159,8	193158	-18,107	-0,000937418		5,755,788	536	-395,788	-7,384,096,601		6,708,026	640	-308,026	-4,812,901,412
209172,8	199534	-9638,76	-4,830,633,557		503,205	540	3,679,504	6,813,896,553		6,219,127	647	2,508,729	38,774,791
238190,1	198473	-39717,1	-2,001,133,411		5,576,939	540	-176,939	-3,276,645,664		6,505,954	641	-959,543	-1,496,947,371
181370	225170	43799,98	1,945,196,131		5,588,256	561	2,174,392	0,387592214		6,544,907	657	2,509,267	0,381927934
206828,2	201420	-5408,16	-2,685,018,861		5,876,725	529	-586,725	-1,109,121,213		6,828,526	632	-508,526	-804,630,361
217058,7	192430	-24628,7	-1,279,878,757		5,374,176	528	-941,762	-1,783,640,571		6,373,852	630	-738,522	-117,225,784
205316,6	201203	-4113,59	-2,044,497,596		5,353,858	545	9,614,161	1,764,066,278		6,328,857	646	1,311,434	2,030,083,022
160858,3	194265	33406,69	1,719,645,317		5,474,477	543	-444,775	-0,819106699		6,545,851	645	-95,851	-1,486,062,306
232433,1	198775	-33658,1	-1,693,276,776		5,074,934	529	2,150,665	4,065,528,397		6,155,072	631	1,549,279	2,455,275,357
231559,1	190135	-41424,1	-2,178,666,993		5,387,267	533	-572,673	-10,744,338		6,329,305	634	1,069,513	0,168692912
206712,8	218591	11878,16	5,433,966,166		5,568,154	535	-218,154	-4,077,644,132		6,641,138	639	-251,138	-3,930,172,602
194925,8	214243	19317,2	9,016,489,352		540,538	544	3,462,009	0,636398741		6,444,597	646	1,540,313	0,238438544
198760	231048	32288,05	1,397,460,492		5,418,732	527	-148,732	-2,822,238,264		6,407,231	628	-127,231	-2,025,968,707
191690,7	226558	34867,34	1,539,002,723		5,045,173	546	414,827	7,597,563,556		6,101,878	645	3,481,219	539,723,886
205575,6	199838	-5737,65	-2,871,149,826		5,343,134	551	1,668,657	3,028,414,728		639,162	652	1,283,801	1,969,020,212
193955,6	213632	19676,44	9,210,435,767		5,232,118	522	-12,118	-0,232145343		6,252,334	623	-223,342	-0,358494827
218079,9	203513	-14566,9	-7,157,720,159		5,063,266	550	4,367,338	7,940,614,966		6,076,995	649	4,130,052	636,371,636
189728,7	203062	13333,32	6,566,132,892		5,312,211	546	147,789	2,706,759,055		6,295,762	646	1,642,384	254,239,043
219953,8	215356	-4597,84	-2,134,995,158		5,573,919	538	-193,919	-3,604,436,987		6,561,465	640	-161,465	-2,522,893,667
223493,2	212287	-11206,2	-5,278,801,869		5,562,468	525	-312,468	-595,177,505		6,514,494	628	-234,494	-3,733,979,682
216836,8	206597	-10239,8	-49,564,122		5,099,771	535	2,502,291	4,677,179,339		6,160,856	635	1,891,438	2,978,641,759
183589,2	214685	31095,81	1,448,438,664		5,414,244	573	3,157,561	5,510,577,398		6,447,845	664	1,921,549	2,893,898,792
223831,2	216369	-7462,22	-3,448,838,912		5,143,952	576	6,160,478	10,695,275		6,158,165	667	5,118,349	7,673,687,205
209876,7	191879	-17997,7	-9,379,733,815		535,746	537	1,253,959	0,233511889		6,357,728	638	2,227,203	0,349091396
201810,8	199357	-2453,83	-1,230,873,566		5,623,783	538	-243,783	-4,531,291,381		6,558,978	642	-138,978	-2,164,765,528
177184,9	198085	20900,07	1,055,106,212		5,033,026	535	3,169,742	5,924,751,121		6,126,942	637	243,058	3,815,667,611
206221,7	204633	-1588,7	-0,776365501		5,314,273	533	1,572,716	0,295068638		6,354,973	634	-149,726	-0,236160935
174005,8	206631	32625,19	1,578,910,474		5,404,479	534	-644,785	-1,207,462,832		6,443,181	638	-631,808	-0,990294218
183801,7	201161	17359,29	8,629,552,407		5,441,141	529	-151,141	-285,710,448		6,426,791	633	-967,909	-1,529,081,584
186090,5	198138	12047,51	6,080,364,082		5,229,774	550	2,702,259	4,913,197,851		6,312,367	651	1,976,325	3,035,829,865
221182,3	204128	-17054,3	-8,354,694,233		523,626	541	17,374	3,211,459,905		6,231,044	644	2,089,558	3,244,655,694
196279,2	204377	8,097,786	396,218,072		5,468,314	545	-183,138	-0,336033172		6,436,565	647	3,343,451	0,516762207
224197,7	194995	-29202,7	-1,497,612,641		5,097,194	548	3,828,057	698,550,565		6,162,519	650	3,374,808	5,192,012,259
172879,3	201938	29058,67	1,438,989,671		5,696,189	553	-166,189	-3,005,219,228		6,680,889	650	-180,889	-2,782,907,805
187698,5	196942	9,243,519	4,693,523,601		555,372	529	-26,372	-4,985,261,995		6,544,349	631	-234,349	-3,713,937,141
217126,3	210404	-6722,32	-3,194,957,516		5,286,569	555	2,634,314	4,746,510,886		6,327,082	654	2,129,179	3,255,624,628
183895,8	203511	19615,18	9,638,388,957		5,170,417	543	2,595,833	4,780,540,086		618,127	644	2,587,297	4,017,541,528
171716,6	208930	37213,4	1,781,141,903		5,295,821	542	1,241,789	2,291,123,365		6,353,856	647	1,161,443	1,795,120,916
208574,9	218060	9,485,052	4,349,743,912		5,633,616	580	1,663,845	2,868,697,783		6,522,427	671	1,875,727	2,795,420,001
188791,3	184786	-4005,3	-2,167,533,537		5,741,544	533	-411,544	-7,721,284,741		6,752,926	635	-402,926	-6,345,291,255
193665,8	201820	8154,2	4,040,332,895		5,601,703	533	-271,703	-5,097,611,527		6,522,466	636	-162,466	-255,449,585
174377,8	219568	45190,17	2,058,140,026		4,925,919	548	5,540,809	1,011,096,599		6,184,844	650	3,151,561	4,848,555,083
	Average	**5,159,602**	**0,066375834**			**Average**	**-0,09595**	**-0,07324758**			**Average**	**0,291442**	**0,016639919**
	Max	**45190,17**	**2,058,140,026**			**Max**	**6,160,478**	**111,806,272**			**Max**	**5,118,349**	**787,106,123**