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PARAMETRIC/GEOMETRICAL MODELLING OF FORGED PART FAMILIES VIA A CAD INTERFACE TOWARDS ON-LINE INTERNET BASED MANUFACTURING AND COST PARAMETER PREDICTION OF DESIGNED PRODUCTS

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ABSTRACT

The co-ordination of work has a critical impact on organisational and business performance. In an era of ever-shorter product life cycles and lead times, it becomes a crucial necessity for companies to manage their internal and external transactions in an efficient, cost-effective way. Information technology has become the major enabler for speeding up communication and improving technical information exchange between the economic actors (customers and suppliers). In this paper we will describe the potential of information technologies for improving the technical information flow in order to reduce the transaction costs of a company. The ability to analyse and predict parameters related to the forging process will greatly improve the designing and manufacturing of forged parts as well as accurately predict the manufacturing costs involved. The research[1] presented in this paper deals with the generation of parametric/geometric forge part family models. The information within these models is used to train backpropagation neural networks for economic and technical parameter prediction. Software were developed, tested and prove the concept viable. The implementation on the Internet as an e-commerce application is suggested.
Keywords: Parametric modelling, Geometrical modelling, E-commerce, Neural Networks

[1] These research results have been achieved within the framework of the *South African-Hungarian Scientific and Technological Co-operation Programme for 2000-2002*.

1. INTRODUCTION

The co-ordination of work has a critical impact on organisational and business performance. In an era of ever-shorter product life cycles and lead times, it becomes a crucial necessity for companies to manage their internal and external transactions in an efficient, cost-effective way.

Information technology has become the major enabler for speeding up communication and improving technical information exchange between the economic actors (customers and suppliers).

In microeconomics approach, the costs of companies can be divided into two groups:

1. *Activity costs*, generally defined as the costs for transformation of production factors (labor, capital, etc.) into products and services (production costs and opportunity costs).
2. *Transaction costs*, generally defined as the costs for gathering information, evaluating alternative options, negotiating, contracting, and the physical transaction of the object through a defined interface.

It can be observed that in the ´90s as a general trend, that beside the given production costs (determined by the applied production technology), the **companies try to reduce their transaction costs**. One of the main factors of the turbulent development and progress in information and telecommunication technologies is to reduce the transaction costs. [1] Actually there is a co-evaluation of the change of business world (organizations) and IT in the sense that the business visions, and plans of organizations trigger the development of IT solutions and vice versa, the availability of IT stimulates the development of different organizational arrangements.

In this paper the potential of information technologies for improving the technical information flow in order to reduce the transaction costs of a company, is describe.

The ability to analyse and predict parameters related to the forging process can greatly improve the designing and manufacturing of forged parts as well as accurately predict the manufacturing costs involved. [2] The research presented in this paper deals with the generation of parametric/geometric forge part family models to accomplish above goal. The above were accomplished by creating an interface in Visual Basic 5, connecting an Access database to SolidWorks, a Windows based CAD system. A forged part family consisting of 40 parts was successfully modelled with one parametric CAD model, containing 91 parameters, which proved the concept to be viable. An expert system or neural network to calculate/predict manufacturing and economic parameters uses these parameters. The possibility exists to implement the system on the Internet incorporating e-commerce.

One of the objectives of the project is to create an Internet interface, which assists the designer of initially forged parts belonging to certain families according to Group Technology (GT) [3][4] principles. The designer’s actions involve the selection of the part family parametric model which best describes his/her design. The parameters of the selected parametric model are modified to very accurately present the designers design. The progress of parameter modification is viewed through a 2D graphical interface. When satisfied the parameters are submitted to the server which includes expert systems/neural networks for manufacturing and economic parameter prediction/calculation. The capture of workpiece features by neural network was reported in [5][6]. The server also uses the parameters to update a parametric CAD model in SolidWorks.

This updated model together with the predicted/calculated parameters and expert system suggestions are sent back to the designer. The designer are then equipped with a full 3D CAD model of his/her design, viewed by a SolidWorks viewer, as well as an evaluation of his/her design in terms of cost, practical implications and manufacturing parameters. The above system will provide a means for a forging design to be evaluated via a very simple interface locally or via the Internet. It would provide accurate information regarding cost and manufacturing parameters. The uniqueness of the system lies in the fact that there are no information lost between the set of parametric parameters and the 3D-geometric/parametric model, thus ensuring that 100% of the information is available to the expert system/neural network for analysis.

2. PARAMETRIC MODEL GENERATION

Initially a set of 10 forging part families, consisting of 40 parts, all of a cylindrical main shape was decided on. These parts are presented in Figure 2.1.

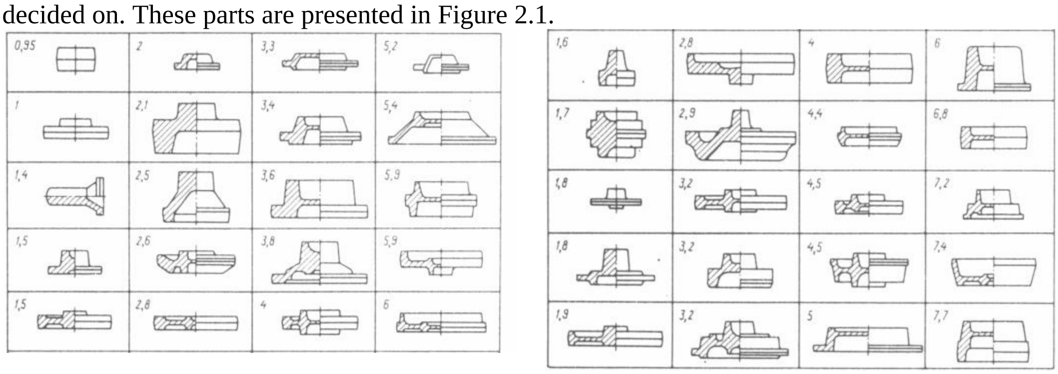
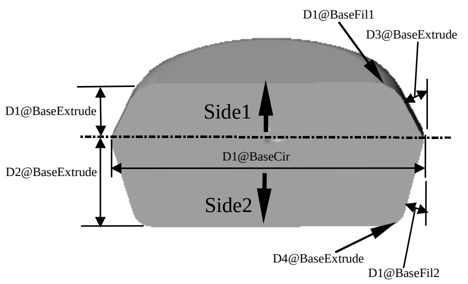


Figure 2.1 Parametric Modelled Parts

Properties	Value	Unit	Description
BaseExtrude	1		Feature -
D1@BaseCir	200	mm	Para - Base circle diameter
Side1	0		
D1@BaseExtrude	160	mm	Para - Base extrude to Side1
D3@BaseExtrude	3	deg	Para - Draft on base extrude to Side1
D1@BaseFil1	2	mm	Feature - Fillet radius on base extrude to Side1
Side2	0		
D2@BaseExtrude	30	mm	Para - Base extrude to Side2
D4@BaseExtrude	8	deg	Para - Draft on base extrude to Side2
D1@BaseFil2	2	mm	Feature - Fillet radius on base extrude to Side2



a) b)

Figure 2.2 Parameters of BaseExtrude a), together with CAD representation b).

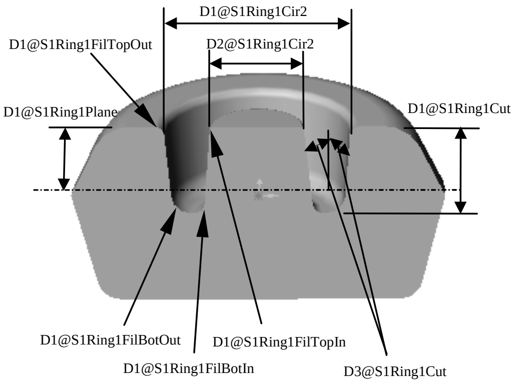
A single parametric model was created in SolidWorks to allow the modelling of all the parts in Figure 2.1. Within the parametric model only three feature types exist. They are as follows:

- **BaseExtrude** - This is an extrusion of a circle to both sides, with drafts and fillets on the respective extrusions. Figure 2.2. a) presents the structure of the model as well as the parameters involved in the BaseExtrude and Figure 2.2. b) presents the CAD representation. The parametric model contains only one such feature. The parametric model is divided into two sides, thus in the directions perpendicular to the base circle plane in opposite directions.
- **RingCut** - This feature presents a cut consisting of the area between two concentric circles at a certain depth from a specified plane. This cut contains a draft angle as well as fillets on all the corners and edges. Figure 2.3 a) present the parameters involved and Figure 2.3 b) the

CAD representation. The parametric model contains six such features, three on each side.(See Figure 3.1)

- **HoleCut** - This feature presents a cut consisting of the area enclosed by a circle at a certain depth from a specified plane. This cut contains a draft angle as well as fillets on all the corners and edges. Figure 2.4 a) present the parameters involved and Figure 2.4 b) the CAD representation. The parametric model contains four such features, two on each side.(See Figure 3.1)

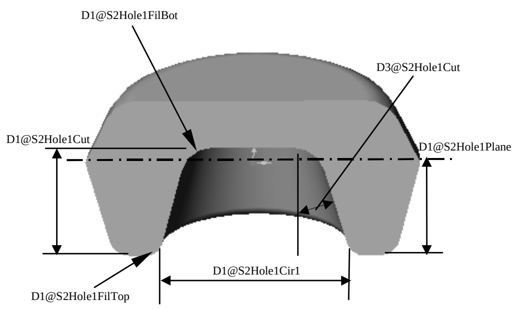
Properties	Value	Unit	Description
S1Ring1Cut	1		Feature -
D1@S1Ring1Plane	160	mm	Para - Plane distance from Origin
D1@S1Ring1Cir2	300	mm	Para - Outer diameter of ring
D2@S1Ring1Cir2	120	mm	Para - Inner diameter of ring
D1@S1Ring1Cut	130	mm	Para - Depth of ring cut
D3@S1Ring1Cut	0	deg	Para - Draft on cut
Fillets	0		
D1@S1Ring1FilTopOut	0	mm	Feature - Fillet radius on top outer edge
D1@S1Ring1FilTopIn	0	mm	Feature - Fillet radius on top inner edge
D1@S1Ring1FilBotOut	0	mm	Feature - Fillet radius on bottom outer edge
D1@S1Ring1FilBotIn	3	mm	Feature - Fillet radius on bottom inner edge
D1@S1Ring1FilEdge	3	mm	Feature - Fillet radius free edge



a) b)

Figure 2.3 Parameters of RingCut a), together with the CAD representation b).

Properties	Value	Unit	Description
S2Hole1Cut	1		Feature -
D1@S2Hole1Plane	30	mm	Para - Plane distance from Origin
D1@S2Hole1Cir1	160	mm	Para - Diameter of hole
D1@S2Hole1Cut	10	mm	Para - Depth of hole cut
D3@S2Hole1Cut	0	deg	Para - Draft on cut
Fillets	0		
D1@S2Hole1FilTop	0	mm	Feature - Fillet radius on top outer edge
D1@S2Hole1FilBot	5	mm	Feature - Fillet radius on top inner edge



a) b)

Figure 2.4. Parameters of HoleCut a), together with the CAD representation b).

A parametric model can thus exist with any combination of three RingCut and two HoleCut features on each Side. In total if all 10 features are used in a part, 91 parameters exist as calculated in Figure 3.2.b. Sub part families can be identified which only use certain of the currently available 10 features.

3. FORGE FORECAST OPERATION

Figure 3.1 presents the 2D graphical interface showing the 2D representation, part feature structure and feature parameters in the grid.

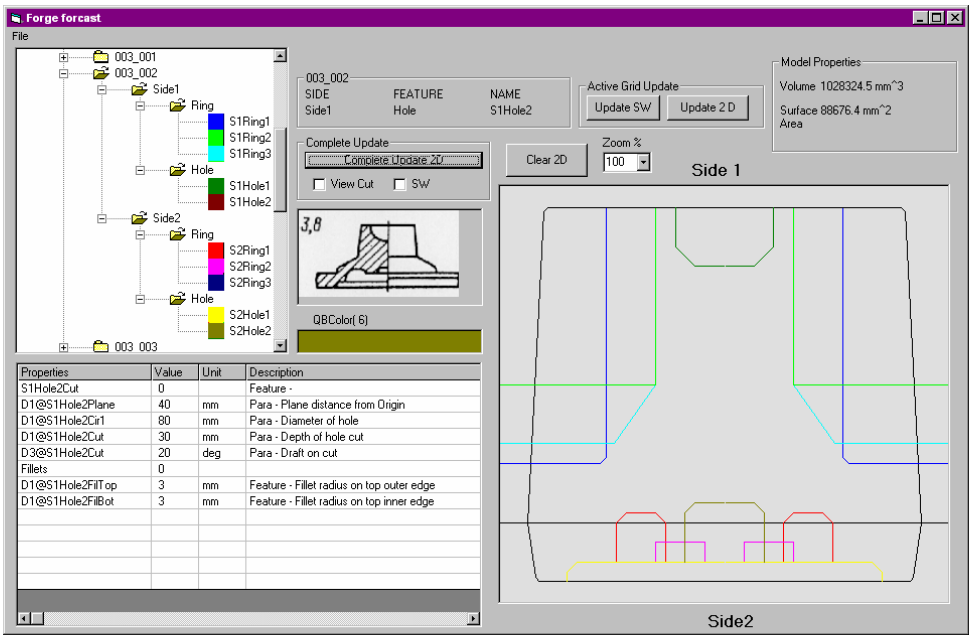
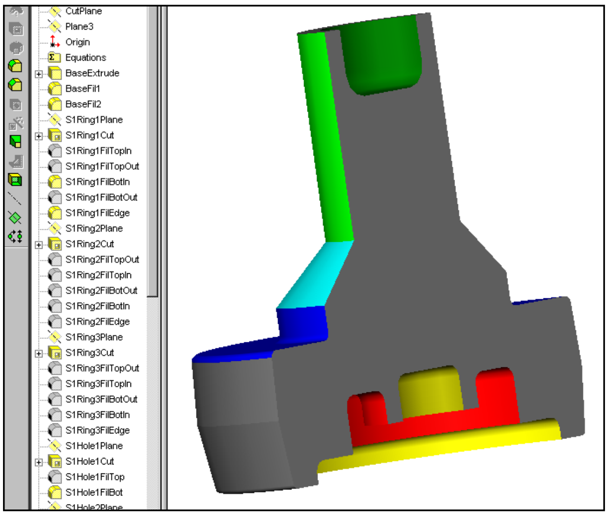


Figure 3.1 2D User interface.



Feature Parameters

• BaseExtrude	1 x 7	=	7
• RingCut	6 x 10	=	60
• HoleCut	4 x 6	=	24
Total Parameters			**91**

a) b)

Figure 3.2 a) Screen shot of SolidWorks sectional cut of the parametric model with specific part parameters loaded. b) Calculation of total number of parameters.

The features in the tree structure, upper right corner, the lines in the 2D interface, lower left corner, as well as the features in the SolidWorks model are colour coded to increase the user friendliness of the software. At start-up the Access database file Forge.mdb is loaded from the install directory. This database includes all existing models, which are displayed in the tree structure. (See Figure 3.1) By clicking on any of the models the BaseExtrude information is displayed in the grid together with a schematic picture of the model. Double clicking on the tabs can open the rest of the data tree structure. When the sub structure of the Ring or Hole tabs is clicked the information regarding the respective feature is displayed on the grid. Only the entries in the Value column of the grid, see Figure 3.1, can be modified by double clicking on it in which case a textbox will appear in which the changes can be made. The changes can be viewed in 2D by clicking the **Complete 2D Update** button. (See figure 3.1)

3.1. UPDATE SOLIDWORKS

Whenever a newly opened model needs to be update to SolidWorks the **Complete 2D Update** button, with the **SW** option checked, is clicked. This action will start SolidWorks, if not already open, and load the part file Forge2.sldprt, if not already loaded. All the parameters within the newly opened model will be updated to SolidWorks. The progress can be watched by looking at the grid, which is loaded with the parameters currently being updated.
Whenever changes are made to the current model, after the above action have been completed, the **Update SW** button can be clicked to update only the parameters currently displayed in the grid to SolidWorks which is less time consuming than updating all the parameters. To disable/suppress any complete feature the Value of the first line in the grid is set to 0. A value of 1 activates the feature. The BaseExtrude feature can not be disabled/suppressed. The **View Cut** ckeckbox allows an option to select a sectional view, through the centre of the part, in SolidWorks.

4. BACKPROPAGATION TRAINING

In order to test the feature capturing ability of the parameters in the parametric model the models in Figure2.1 were each modelled 3 times, to look the same, but with different dimensions and fillets, all with a base diameter of 200 mm. In total 120 models each containing 91 parameters were available as input training sets.

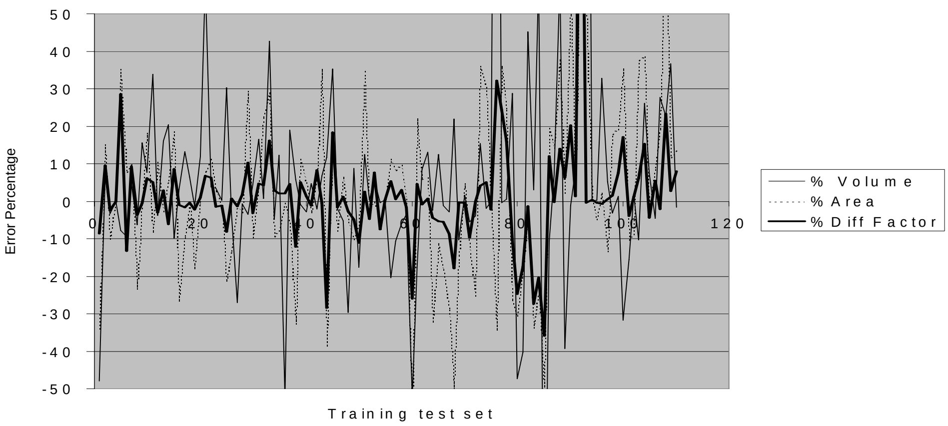


Figure 4.1 Training test set errors

The output target sets were three parameters namely the volume and surface area which are calculated by SolidWorks, see upper left corner of Figure 3.1, as well as the difficult factor, relating to the difficulty estimation of the manufacture of the part. (See upper left corner of parts in Figure 2.1) A backpropagation network, with one hidden layer of 12 neurons, using the above training data was repeatedly trained in the following manner:
Since a relatively limited amount of training sets versus the input parameters existed the backpropagation network were trained repeatedly while removing two training sets for use as training test sets for each training session. The testing sets were chosen to be 5 sets apart starting at training set 1 to 120. All sets were trained to an error of 0.01. Figure 4.1 presents the percentage errors when testing the training test sets. In certain areas of the graph the errors are within 20 %. The additions of more models as training sets are suggested for further improvement of the errors.

5. FURTHER DEVELOPMENT

With the above interface all the parameters are updated to the SolidWorks model as well as save and retrieved from an Access database. However the above system does not prevent the selection of invalid parameter combinations that would result in errors in the SolidWorks model. An expert system that would first analyse the parameters before updating the SolidWorks model is suggested. The rule base of such an expert system would include rules like the outer diameter of a RingCut feature should not be smaller than the inner diameter etc.
Once the expert system is able to allow only valid parameter combinations another rule base, which includes the rules for analysing the difficult factor, and cost implications can be added. Cost and other manufacturing parameters can also be predicted by a backpropagation neural network with input the parameters in the parametric model.

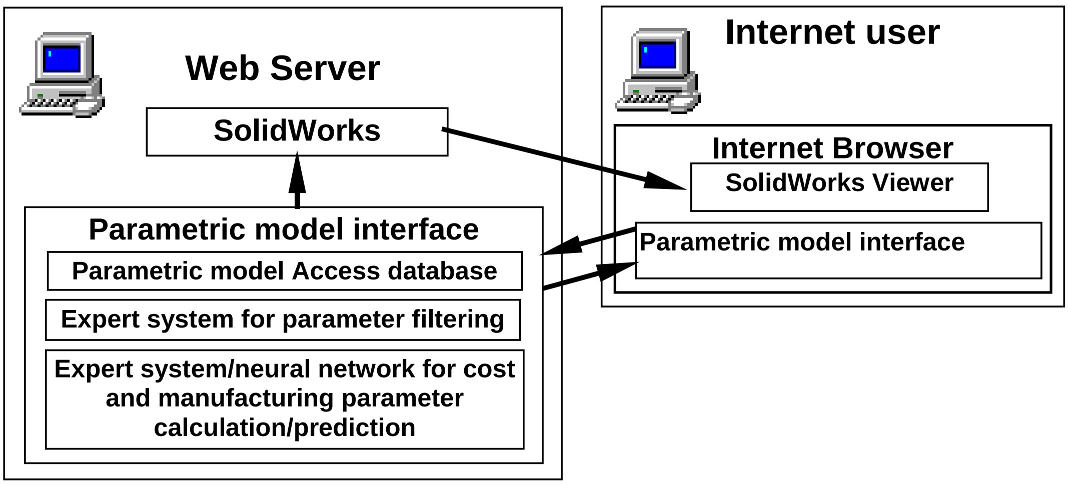


Figure 5.1 Suggested Internet based system

Figure 5.1 presents the functioning of a suggested Internet based system. The Internet user will be able to access the web page containing the Parametric model interface. (created by Java/VB script/Java script or other technologies) The existing models including a schematic, like in Figure

2.1, will be presented to the user. The user can then modify the closest matching model to his requirements and submit the changes via the web based 2D interface similar to Figure 3.1. The Parameter filtering expert system will notify the user if invalid parameter values/combinations have been selected and will also advise on some valid values/combinations. Once a valid parameter set has been selected the web server will update the SolidWorks model. The expert system/neural network for cost and manufacturing parameter calculation/prediction will then user the SolidWorks model parameters and properties to predict/calculate the various parameters.
The predicted parameters together with the updated SolidWorks part file will be sent to the Internet user. The new parameters are then viewed by the user in the 2-D interface and the SolidWorks part file in the SolidWorks Viewer. The current parametric SolidWorks part file is only 320 KB large. The SolidWorks Viewer is available free of charge and is activated from within the web browser.
The above system can be expanded to include various part families together with the respective parametric models. For a specific company it might be of great value to have the above system on its Intranet.

6. REFERENCES

[1] Hoffman Z., Dadvandipour S., ”Reducing Company Transaction Costs by Application of Information Technologies.”, Proceeding of MicroCAD´99 International Computer Science Conference, Miskolc, February 1999., pp: 83-89.

[2] Bengoa A., Hoffman Z., “Cost estimation and generation of offers for mechanical workpieces.”, Journal of Engineering Manufacture.(submitted for publication)

[3] Choi M., “GT Coding and Classification Systems for Manufacturing Cell Design”, Production and Inventory Management Journal, Vol.32, no.1, pp. 28-32,1991.

[4] Opitz H., “ A Classification System to Describe Workpieces”, Oxford, Pergamon Press, Oxford, 1970.

[5] Naude J., “A Neural-network/Expert system based approach for design improvements of Products Manufactured by the EDM Process”, Master Thesis, Rand Afrikaans University, Johannesburg, South Africa, 1995.

[6] Katz Z. and Naude J., “A Neural Network/Expert System Approach for Design Improvements of Products Manufactured by EDM.” Journal of Manufacturing Science and Engineering, JMSE, August 1999.

[7] Cser L. - Tamás P.,” "Orbis Pictus" and the Integrated CAD/CAM System Beyond Number Crunching”, Retzhof, 1988.

GEOMETRIJSKI/PARAMETARSKO MODELOVANJE OTKOVAKA POMOĆU CAD INTERFACE-A U CILJU KREIRANJA ON-LINE PROIZVODNJE I PRORAČUNA TROŠKOVA NA BAZI INTERNETA

J. Naude, Z. Hoffman, L. Cser, and P. Tamas

REZIME

Koordinacija poslova u okviru jedne firme je od esencijalnog značaja na rezultate poslovanja i organizacije. U eri kada je ciklus uvođenja novih proizvoda sve kraći, upravljanje internim i eksternim transakcijama i informacijama u okviru jedne organizacije predstavlja jedan od osnovnih preduslova za uspešnost poslovanja. Informaciona tehnologija je postala glavni promotor u širenju komunikacija i razmeni tehničkih informacija između ekonomskih subjekata (proizvođača i potrošača). Ovaj rad opisuje potencijal informacionih tehnologija na planu poboljšanja toka tehničkih informacija a u cilju smanjenja ukupnih troškova firme.

Sposobnost da se odrede i analiziraju osnovni parametri procesa kovanja u velikoj meri poboljšava konstrukciju i izradu otkovaka uz istovremeno smanjenje ukupnih troškova proizvodnje. U okviru ovog rada opisana je familija modela otkovaka koja je generisana na geometrijsko/parametarskim principima. Informacije koje su dobijene na ovaj način korišćene su neuralnim mrežama za određivanje ekonomskih i tehničkih parametara procesa. Razvijen je i testiran software a sugeriše se i primena na internetu, kao jedan od vidova ekonomske aplikacije.