PARAMETRIC MODELING OF HYDRODYNAMIC COUPLING IN CAD ENVIRONMENT

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Abstract: *Hydrodynamic coupling is important part in a power transmission. Due to that fact, optimal as well as fast design of the impeller is concerned. In this study numerical model for calculation of the impellers main geometrical parameters is developed in the MS EXCEL software package and appropriate data are then imported in AutoDesk package INVENTOR. These data are used in CAD environment as parameters for automatic pump and turbine impellers generation.*

In this paper mathematical model, numerical algorithm as well as application of developed software is presented. This method is used for design of small and medium power hydrodynamic coupling.

KEYWORDS: HYDRODYNAMIC COUPLING, MATHEMATICAL MODEL, DESIGN, CAD

1. INTRODUCTION

Hydrodynamic coupling basically consists of an impeller and a turbine contained in a suitable housing. The primary wheel is connected to input shaft and the secondary one to output shaft. It transmits the engine torque to the transmission. In principle, transmittable torque of completely filled coupling increases continuously with decreasing speed ratio down to almost 0 [1]. Hydrodynamic coupling can be best classified into two main groups according to application. One group comprises starting and slip couplings with a constant oil filling. The other group comprises variable-speed couplings that require and enable variations in the degree of filling during operation for speed control [2,3].

Today, hydrodynamic couplings are widely applied in transmission of energy in all branches of industry: transport means, process equipment for leather, food and chemical industry, and mining, machinery for metal, wood and textile treatment and etc.

The aim of this paper is to present a method of parametric modeling for fast design of the main parts of a hydrodynamic coupling. It is based on AutoDesk Inventor interacting with Microsoft Excel spreadsheet program. Presented method provides a tool for automatic 3D model generation of the hydrodynamic coupling pump and turbine impeller in CAD environment.

2. MATHEMATICAL MODEL

Calculation of geometrical parameters of a hydrodynamic coupling is based on one – dimensional model of fluid flow, and on the theory of conformity. Main purpose of this calculation method is to provide means for designing a hydrodynamic coupling corresponding to predefined working characteristics.

Starting inputs that will be used for determining the geometrical parameters of hydrodynamic coupling are defined by design requirements. These requirements necessarily include:

- P – Power transmitted to the pump shaft by driving machine
- n_p – pump shaft speed
- η efficiency of the cluch
- ρ – working fluid density
- ρ_s – model – coupling working fluid density
- p – working pressure.

Calculation of hydrodynamical coupling geometrical parameters can be represented according to next algorythm [1, 4, 5,6]:

1. Specific shaft speed $n_{sp}[rpm]$

2. Pump head $[m]$:

$$H_p = \left[n_p \left(\frac{\rho_s}{\rho} \right) \frac{(P \cdot \eta)^{1/2}}{n_{sp}} \right]^{4/3}$$

3. Discharge flow $[m^3/s]$:

$$Q = \frac{P \cdot 10^3 \cdot \eta}{\rho \cdot g \cdot H_p}$$

4. Pump shaft speed $[rad/s]$:

$$\omega_p = \frac{\pi \cdot n_p}{30}$$

5. Meridian component of fluid velocity $[m \cdot s]$:

$$c_m = 0{,}06 \cdot \sqrt{2 \cdot g \cdot H_p}$$

6. Inlet area (A_i) and outlet area (A_o) of impeller $[m^2]$

$$A_i = A_o = \frac{Q}{c_m}$$

7. Pump and turbine diameters $[m]$:

$$\nu = \frac{D_0}{D} = 0{,}4$$

$$m = \frac{r_i}{r_e} = \frac{1+3\nu^2}{3+\nu^2}$$

$$r_e = \sqrt{\frac{g \cdot H_p}{\omega_p^2 (1 - \iota \cdot m^2)}}$$

$$r_i = m \cdot r_e .$$

Impeller inlet (b_1) and outlet (b_2) width $[m]$:

$$b_2 = \frac{Q}{2 \cdot \pi \cdot r_e \cdot c_m}, \quad b_1 = \frac{Q}{2 \cdot \pi \cdot r_i \cdot c_m}$$

where:

$$D_0 = 2 \cdot r_i - b_1$$

$$D = 2 \cdot r_e + b_2$$

8. Number of pump impeller blades:

$$Z_1 = 8{,}65 (D \cdot 1000)^{0{,}278}$$

9. Number of turbine impeller blades:

$$Z_2 = Z_1 \pm 2$$

3. USING PARAMETERS IN AN AUTODESK INVENTOR MODEL

Using mathematical model presented in previous chapter, numerical algorithm for calculation of main dimensions of a pump as well as a turbine impeller is developed. For that purpose, Microsoft Excel spreadsheet platform was used. Geometrical modeling of the hydrodynamic coupling's prototype was carried out in AutoDesk Inventor environment because of possibility to use parametric modeling approach as well as an external application for calculation.

Each dimension or other measurement added to a model is automatically established as a parameter of a model. Such parameters can be used in equations from which other parameters are derived.

In case of using the same parameters in various models, parameters can be defined in Microsoft Excel spreadsheet, which in turn, can be embedded or linked to the Inventor parts or assemblies.

MS Excel spreadsheet containing the model parameters is required to be in the following format:

- The data can start in any cell of the spreadsheet.

- The data items can be in rows or columns, but they must be in the correct order: parameter name, value or equation, unit of measurement, comment.

- The parameter name and value are required; the other items are optional.

- If units of measurement for a parameter are not specified, the default units for the model are assigned when you use the parameter. To create a parameter without units, enter UL in the units cell.

- Column or row headings or other information can be included in the spreadsheet, but they must be outside the block of cells that contains the parameter definitions.

54	R	247.052	mm
55	re	222.197	mm
56	rm	178.375	mm
57	ri	104.067	mm
58	r0	50.998	mm
59	Du	40.000	mm
60	Ds	80.000	mm
61	SL	18.000	mm
62	Zp	49.000	ul
63			

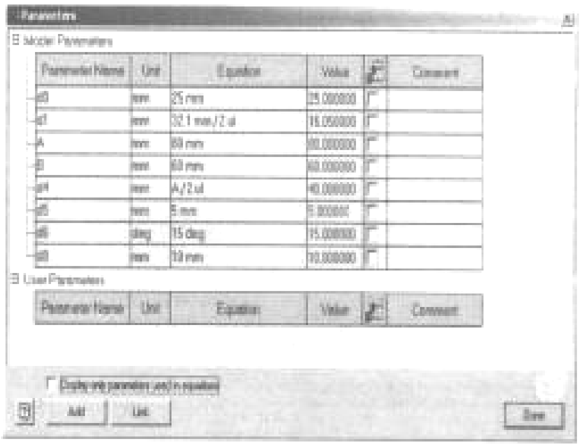
1. Example of a table of parameters

Once created, a parameters spreadsheet can be used to drive the dimensions of a model or parameters of features applied to a model.

Spreadsheet is linked to the model by selecting the "parameters" ( ) button from the Standard Toolbar, clicking the Link button after the Parameters dialog – box appears, and specifying the starting cell of the spreadsheet in the Open dialog – box, followed by clicking Link button in the same dialog.

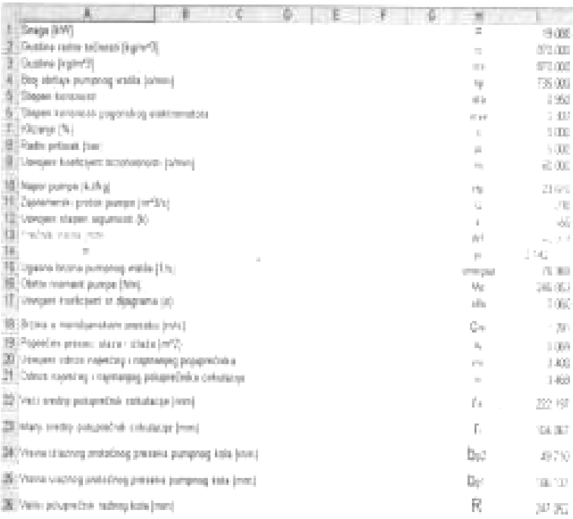
After a parameters spreadsheet has been successfully linked to the model, list of model parameters in the Parameters dialog – box will be updated, and it will resemble the one in the Figure 2.

By linking an Excel spreadsheet to Inventor model, one can simplify the process of generating similar models based on the same parameters, and even completely automatize a design of series of products sharing the same geometrical shape.



2. Constant parameters model table

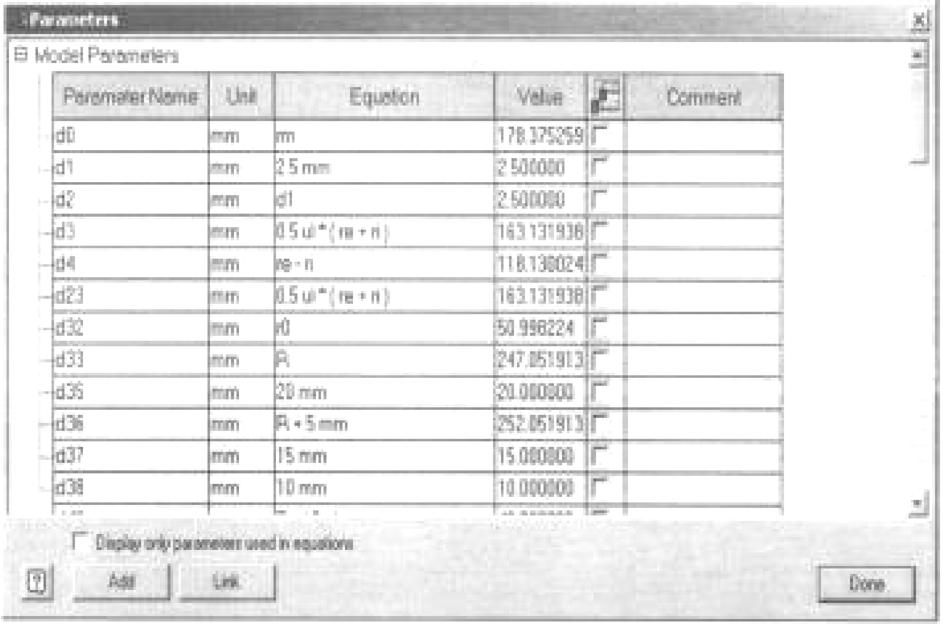
Automatization of the design of series of products begins with a creation of a spreadsheet containing the appropriate calculation of model geometrical parameters based on relevant inputs. An example of calculation of hydraulic coupling geometrical parameters, containing a list of relevant inputs is shown in the Figure 3.



3. Model parameters calculation spreadsheet

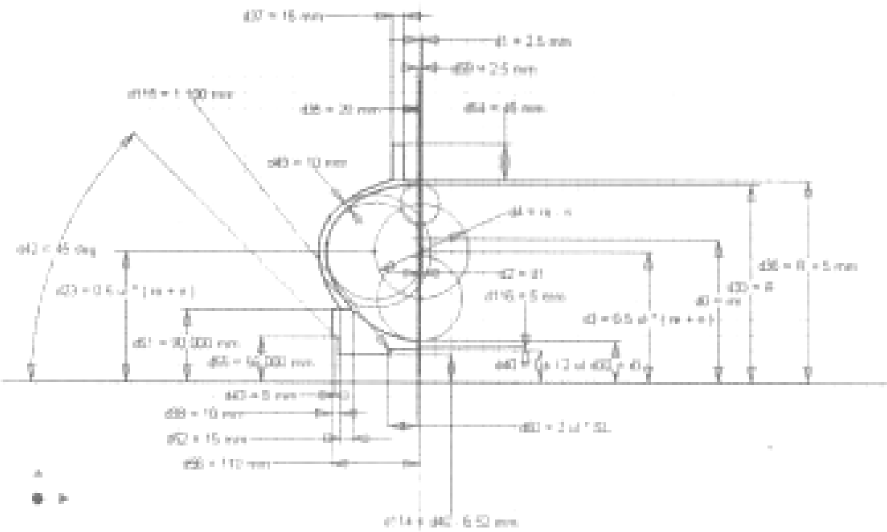
By changing the values of inputs, the values of model parameters are changed, thus creating a model which dimensions and working features can be actively driven by those values. Inputs relevant for the model can be: transmitted power or torque required, shaft speed, etc. Creating a model with spreadsheet – driven parameters, once it is linked to an Excel worksheet, amounts to a regular Inventor sketching/modeling process, with an exception that actual values of sketch dimensions and defining values of work features applied to a model are not entered, but replaced by their names as defined in table of parameters.

Examples of table of parameters of a completed part, as well as an Inventor sketch created using a parameters spreadsheet are shown in the figures 4-6.

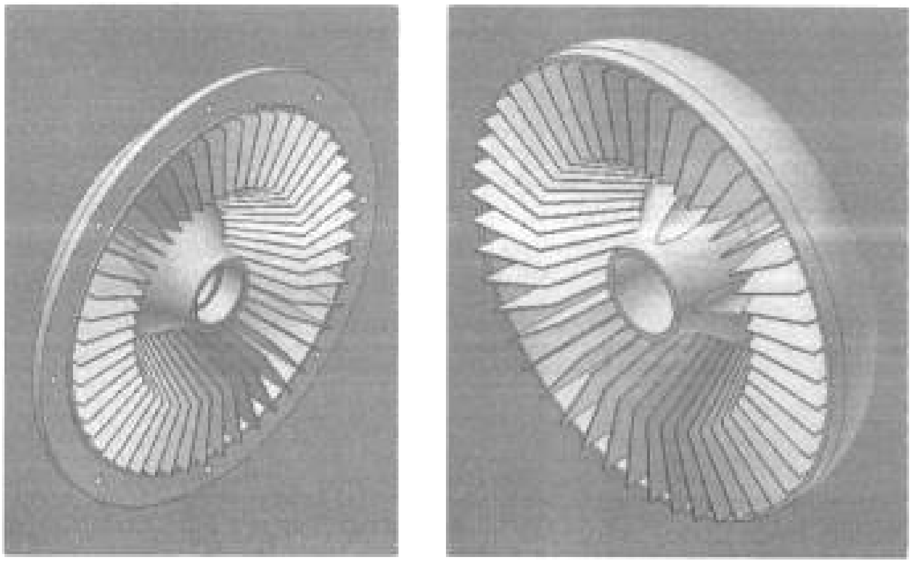


Parameter Name	Unit	Equation	Value		Comment
d0	mm	rm	178.375259		
d1	mm	2.5 mm	2.500000		
d2	mm	d1	2.500000		
d3	mm	0.5 ul * (re + ri)	163.131938		
d4	mm	re - ri	118.130024		
d23	mm	0.5 ul * (re + ri)	163.131938		
d32	mm	r0	50.998224		
d33	mm	R	247.051913		
d35	mm	20 mm	20.000000		
d36	mm	R + 5 mm	252.051913		
d37	mm	15 mm	15.000000		
d38	mm	10 mm	10.000000		

4. Table of parameters of an actively driven model



5. Parameter driven model sketch



6. 3D models of the pump and the turbine impeller

4. CONCLUSION

After reviewing the mathematical basics of hydrodynamic coupling development, this article elaborates a method for automation of hydrodynamic coupling 3D-model development.

The method provides a tool for automatic generation of hydrodynamic coupling pump and turbine impellers 3D models, in AutoDesk Inventor environment, based on Inventor interacting with Microsoft Excel spreadsheet program. Geometrical parameters are determined using the calculating algorithm provided in the chapter 1 of this paper. Means for linking of AutoDesk Inventor 3D models and Microsoft Excel spreadsheet are discussed in chapter 2.

The intention of the presented project was to provide the engineers with the tool for hydrodynamic coupling design, without a deeper knowledge of hydrodynamic aspects of the coupling or methods for its mathematical description. Considering that the coupling parts relevant in terms of hydrodynamics are generated automatically, engineers would only be required to design the parts of the coupling that are not of hydrodynamic importance.

5. REFERENCES

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