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COMPUTER AIDED ENGINEERING IN MODELING OF HYDRODYNAMIC COUPLING

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

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COMPUTER AIDED ENGINEERING IN MODELING OF HYDRODYNAMIC COUPLING

UDC: 621.838.4

1. INTRODUCTION

The hydrodynamic coupling, also called *Föttinger* coupling, is important part in a power transmission. Generally he consists of a pump wheel connected to the engine and a coupling-ended turbine that is equipped with uniform, radial vanes. A torque is transferred between the pump wheel and the turbine over a fluid which is accelerated by the pump and decelerated in the turbine (Coriolis effect) [1]. The hydrodynamic coupling can partially dissipate thermal losses over the working fluid. Consequently the speed conversion is not limited over time (Fig.1). In principle, the transmittable torque of completely filled coupling increases continuously with decreasing speed ratio down to almost 0.

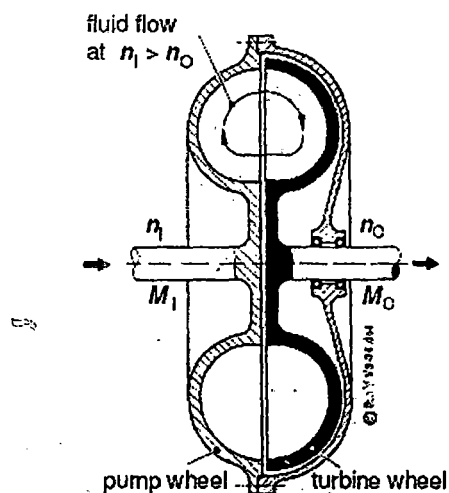


Figure 1. Hydrodynamic coupling [1]

Hydrodynamic coupling can best be classified by dividing them into two main groups according to application. One group comprises starting and slips coupling with constant filling, and the other variable-speed coupling requiring and enabling variations in the degree of filling during operation for speed control.

Couplings with constant filling level are totally enclosed, and have to be filled with the correct level of operating fluid prior to startup. The filling level is defined as the ratio of fluid volume to total coupling capacity, and thus determines the coupling characteristics. The startup characteristics of couplings with constant filling level can be varied by the controlled filling of auxiliary chambers. Couplings with constant filling level are mainly used for startup, torque limitation and for dampening torsional vibrations.

Variable-speed scoop tube and fill-controlled couplings enable the stepless variation of power transmission, mainly by altering the filling level. For this reason they always have an external fluid circuit, which serves for cooling as well as varying the filling level. The filling level can be varied by means of a radially adjustable scoop tube, or control valves [2], [3].

Today, hydrodynamic couplings are mainly used in transmission of energy in all branches of industry: transport means (stationary drives and automobile technology, marine applications), process equipment for leather, food, chemical industry and mining, machinery for metal, wood and textile treatment and etc. Analyses of various aspect of this hydrodynamic system has already conducted and presented in literature [4],[5].

In this paper, a method for fast design of the main parts of a hydrodynamic coupling using parametric modeling is presented. The method provides a tool for automatic generation of the hydrodynamic coupling pump and turbine impeller 3D models in CAD environment, based on AutoDesk Inventor interacting with Microsoft Excel spreadsheet program.

Due that fact, optimal as well as fast design of the impeller is concerned. Numerical model for calculation of the blade main 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 blades generation. 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 [6].

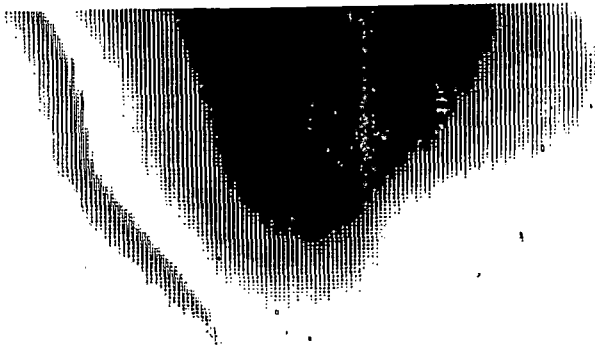
2. MATHEMATICAL MODEL

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,





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η – efficiency of the clutch,
 ρ – working fluid density,
 ρ_s – model – coupling working fluid density,
 p – working pressure.

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Calculation of hydrodynamical coupling geometrical parameters can be represented according to next algorithm [6, 7, 8, 9]:

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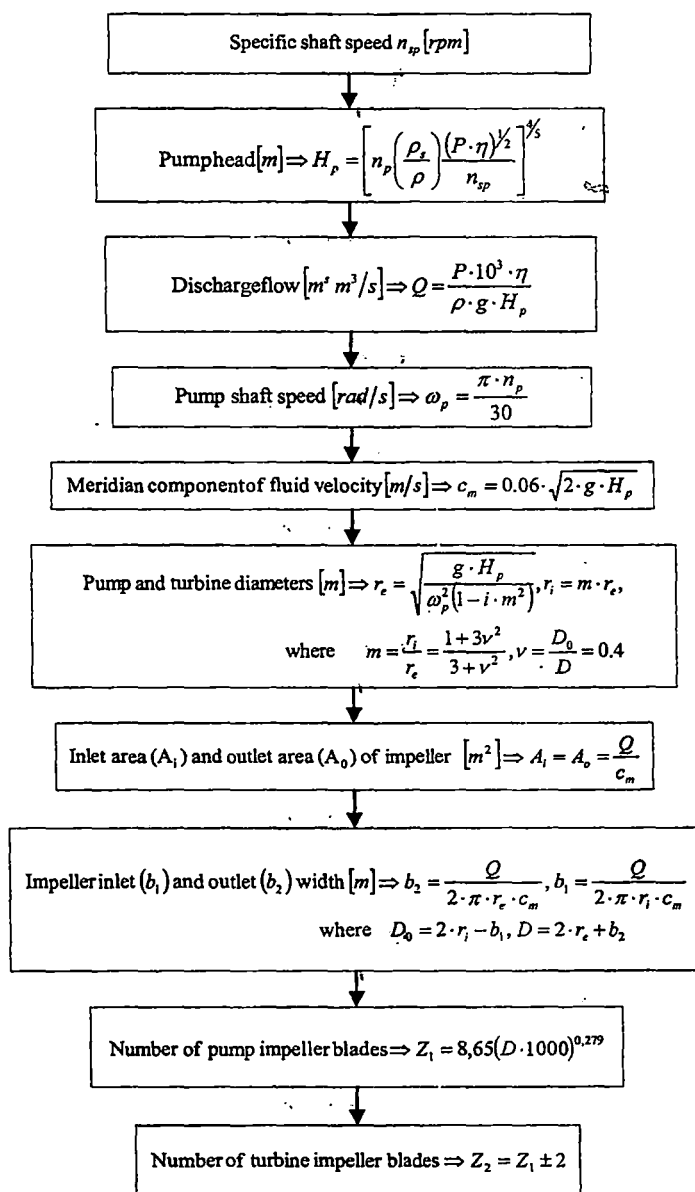
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3. USING

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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 [6].

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	rd	50.998 mm
59	Du	40.000 mm
60	Ds	80.000 mm
61	SL	18.000 mm
62	Zp	49.000 ul
63		

Figure 2. 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 (Fig. 2).

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 3.

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.

Parameter Name	Unit	Equation	Value	Comment
d0	mm	25 mm	25.000000	
d1	mm	32.1 mm / 2 ul	16.050000	
A	mm	80 mm	80.000000	
B	mm	60 mm	60.000000	
d4	mm	A / 2 ul	40.000000	
d5	mm	5 mm	5.000000	
d6	deg	15 deg	15.000000	
d8	mm	10 mm	10.000000	

Parameter Name	Unit	Equation	Value	Comment
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☐ Display only parameters used in equations

Figure 3. 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 4.

Examples of
a parameter

	A	B	C	D	E	F	G	H	I
1	Snaga [kW]							P	19.000
2	Gustina radne tečnosti [kg/m ³]							ro	870.000
3	Gustina [kg/m ³]							ros	870.000
4	Broj obrtaja pumpnog vratila [o/min]							np	735.000
5	Stepen korisnosti							eta	0.950
6	Stepen korisnosti pogonskog elektromotora							etae	0.900
7	Kiszanje [%]							s	5.000
8	Radni pritisak [bar]							pr	5.000
9	Usvojeni koeficijent brzohodnosti (o/min)							ns	60.000
10	Napor pumpe [kJ/kg]							Hp	23.610
11	Zapreminski protok pumpe [m ³ /s]							Q	0.090
12	Usvojeni stepen sigurnosti (k)							k	1.450
13	Tečnič vratila [mm]							dvl	42.3/4
14	π							pi	3.142
15	Ugaona brzina pumpnog vratila [1/s]							omegap	76.969
16	Obrtni moment pumpe [Nm]							Mp	246.953
17	Usvojeni koeficijent iz dijagrama (a)							alfa	0.060
18	Brzina u meridjanskom preseku [m/s]							Cm	1.291
19	Poprečni preseci ulaza i izlaza [m ²]							Ai	0.069
20	Usvojeni odnos najvećeg i najmanjeg poluprečnika							mi	0.400
21	Odnos najvećeg i najmanjeg poluprečnika cirkulacije							m	0.468
22	Veći srednji poluprečnik cirkulacije [mm]							fo	222.197
23	Manji srednji poluprečnik cirkulacije [mm]							fi	104.067
24	Visina izlaznog protočnog preseka pumpnog kola [mm]							bp2	49.710
25	Visina ulaznog protočnog preseka pumpnog kola [mm]							bp1	106.137
26	Veliki poluprečnik radnog kola [mm]							R	247.062

Figure 4. 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 5-7.

Parameters					
Model Parameters					
Parameter Name	Unit	Equation	Value		Comment
d0	mm	m	178.375259		
d1	mm	2.5 mm	2.500000		
d2	mm	d1	2.500000		
d3	mm	$0.5 \cdot d1 \cdot (re + ri)$	183.131938		
d4	mm	$re + ri$	118.110024		
d23	mm	$0.5 \cdot d1 \cdot (re + ri)$	183.131938		
d32	mm	d0	50.999224		
d33	mm	R	247.051913		
d35	mm	20 mm	20.000000		
d36	mm	$R + 5 \text{ mm}$	252.051913		
d37	mm	15 mm	15.000000		
d38	mm	10 mm	10.000000		

Figure 5. Table of parameters of an actively driven model

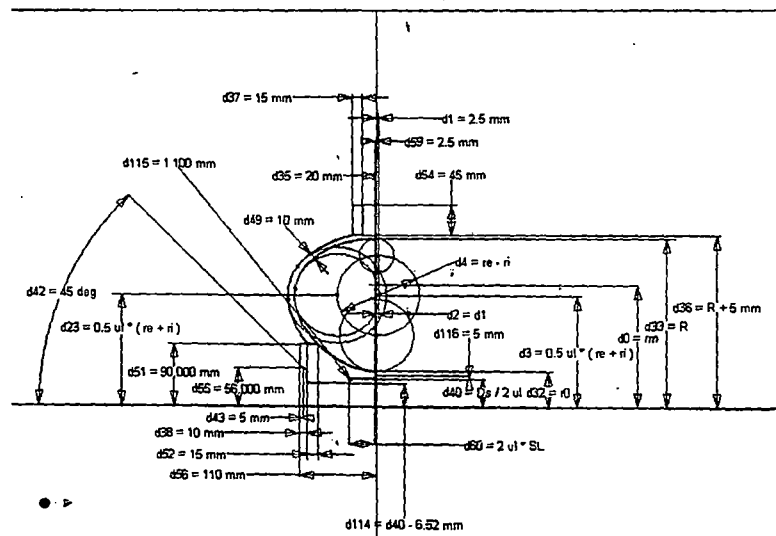


Figure 6. Parameter driven model sketch

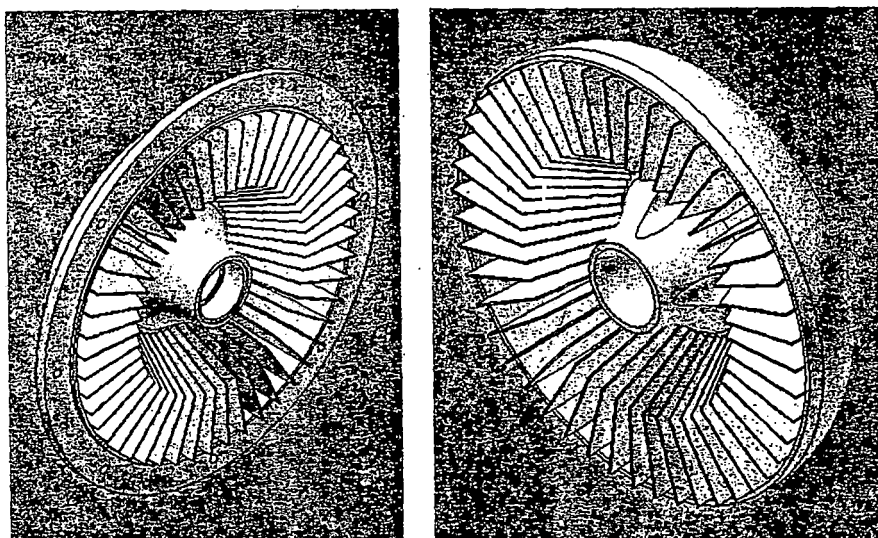


Figure 7. 3D models of the pump and the turbine impeller

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 first part of this paper. Means for linking of AutoDesk Inventor 3D models and Microsoft Excel spreadsheet are discussed in the second part.

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.

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