AN APPROACH TO PLATFORM DESIGN USING DESIGN AND PERFORMANCE PARAMETERS INTERACTIONS

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ABSTRACT

To respond to the challenge of agile manufacturing, companies are striving to provide a large variety of products at a low cost. The key to a successful product platform from which it is derived either by adding, removing, or substituting one or more modules to the platform or by scaling the platform in one or more dimensions to target specific market niches. The objective of this study is to investigate effect performance parameter to design. Modular approach in platform architecture will produce many products from limited number of components. In this research centrifugal pump will be used as case study. In pump design only parameters such as number of impeller, input angle and so will influence product performance from the aspect of its shape a form, dimension and geometry.

Keywords: platform, modules, performance design, platform architecture.

INTRODUCTION

Today's marketplace is highly competitive, global and volatile: customer demands are constantly changing, and they seek wider varieties of products at the same price as mass-product goods. This new shift in the market has increased the need for product variety, in which variety and customization replace standardized products [1].

To respond the challenge of agile manufacturing, companies are striving to meet the market changes requirements at a low cost. Especially of modular products provides challenges and opportunities for the design of assembly systems.

Simply stated, a product family is a group of related products that share common characteristics, which can be outer features, components, or subsystems. The key to designing a successful product family is the product platform. In general, a platform is "the lowest level of relevant common technology within a set of products or a product line" [2].

Many companies are using platform-based product families that provide sufficient variety for the market while maintaining economies of scale and scope within their manufacturing processes. In general terms, a product family is a group of related products that is derived from a product platform to satisfy a variety of market niches. By sharing components and production processes across a platform of products, companies can develop differentiated product efficiently, increase the flexibility and responsiveness of their manufacturing processes, and take a market share away from competitors that develop only one product at time [3]. Platform based product development offers a multitude of benefits including reduced development time and system complexity, reduced development and production costs, and improved ability to upgrade products.

Platforms also promote better learning across products and can reduce testing and certification of complex products such as aircraft [4], spacecraft [5], and aircraft engines [6]. In the automotive industry, platforms also enable greater flexibility between plants and increase plant usage-sharing underbodies between models can yield a 50% reduction in capital investment. Firms using a platform-based product development approach in the automotive industry recently gained a 5.1 percent market share per year while firms that did not loss 2.2 percent [7].

The objective of this research is to identify the relationship between design parameter, geometry and system performance. Modular approaches adopter parameter mapping to identify the platform. In this research centrifugal pump is used as case study.

APPROACH

For a given product, there will be mathematical equations, which relate main specifications with the operational parameter and design parameter. The approach is show in Fig. 1.

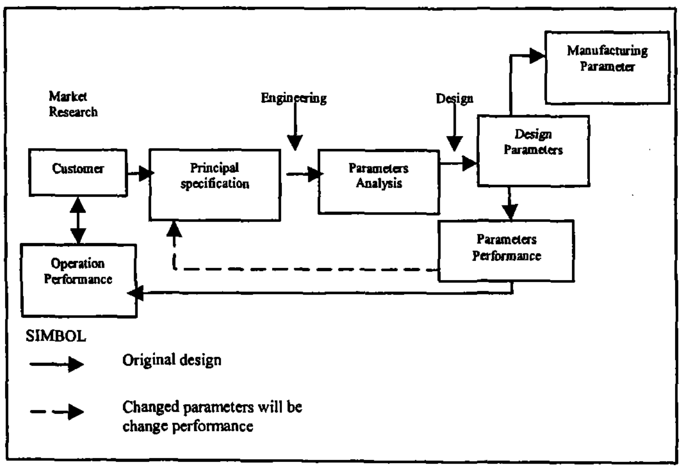

Fig.1: Overall process relationship parameters

All the parameters will be listed and relationship between parameters will be identified via related mathematical equations with system or machine intended for design. For cases where, no direct equations exist, simulation result from various numerical methods can also be used. Then matrix interaction from that design parameter is build.

Matrix interaction will give the entire relationship between, specification parameter, operation and design. Interaction value will be determined based on the mathematical equation, which indicates the parameters effect on each other. For example:

$\eta = QH/P$,
Where,
η = efficiency
H = head
Q = flow rate

$H = Pv^2/2g$
Where,
P = power
v = velocity
g = specific gravity

The interaction in the interaction matrix as in Figure 2. Parameters which have no relationship will be marked as zero.

	η	v	Q	H	P
η	X		1	1	-1
v		X		2	
Q	1		X		
H	1	2		X	1
P	-1			1	X

Fig. 2: Construction matrix interaction

From there the parameters can be clustered with highest interaction density by using Triangularization Algorithm [8].

Followed by mapping between clustered parameters with components related with those parameters. Such as, N (pump revolution speed), η (pump efficiency), H(head), and z (no. of vanes) are related with impeller and volute. Interaction density can be used to identify which component is more relevant. Figure 3 below indicates matrix interaction and module identified.

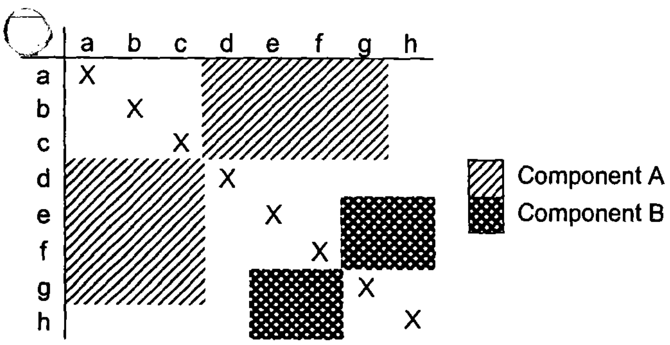

Fig. 3: Cluster effect on matrix interaction

And finally is the new design based on the interaction for future upgrade machine by platform design and the design is subjected to further calculation.

CASE STUDY

In this study a centrifugal pump is selected for case study as shown in Figure 4.

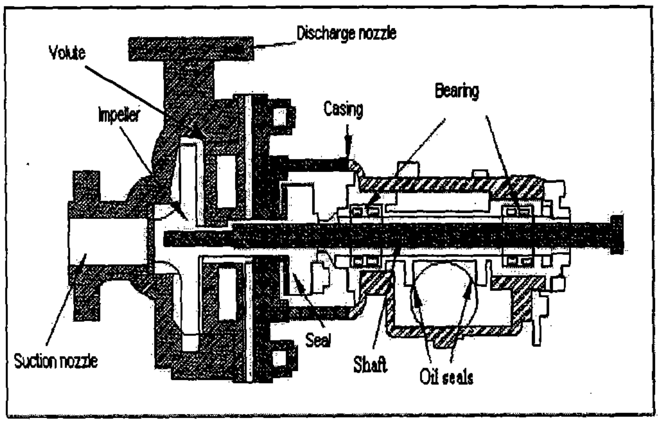

Fig 4: Cross section of centrifugal pump

COMPONENTS

Basically centrifugal pump consist of seven major components as follows.

i. Impeller
ii. Volute
iii. Casing
iv. Shaft
v. Seal
vi. Bearings
vii. Oil seals

Three components that greatly influence the pump performance are the impeller, casing and which directly in which influencing the pressure and flow rate [10] and [11].

Pump Performance

In measuring pump performance, there are 5 major parameters that have influence on pump performance [10].

i. Flow rate – Q
ii. Head– H
iii. Input power – P
iv. Efficiency - η
v. Speed – N

From those performance Q,H, P and η are output parameters where N is the input parameter to the system (N is the motor output)

a). Impeller

The selection of impeller design is mainly based on the specific speed as reproduced below based on the specific speed as reproduced below based on the work by [11].

Flow rate, Q is:

$$Q = AV \quad (1)$$

where,

Q – flow rate ($Q = m^3/s$)

A – cross section area (mm^2)

V - velocity (m/s)

And head, H is,

$$H = \eta_H (U_2 V_{u2} - U_1 V_{u1})/g \qquad (2)$$

Where,

η_H –fluid efficiency (0.85 – 0.95)

1 - Input

2 - Output

Pump efficiency η,

$$\eta = \frac{vQH}{P} \qquad (3)$$

Where,

v – Specific speed

Q – Flow rate

H – Head

P – Power

From a user's perspective optimum hydraulic design is synonymous with optimum efficiency. A less obvious, but well established fact is that optimum hydraulic design is also, in general, synonymous with improved reliability. As a rule, increased hydraulic efficiency results in reduced hydraulic disturbance and since the forces transmitted to the bearings are virtually all hydraulically generated, an optimized hydraulic design will minimize these forces. This results in reduced shaft deflection and reduced bearing loads which, in turn, leads to improved life of mechanical seals and bearings. The key to inherently reliable and efficient pumps therefore lies in the hydraulic design.

Probably the most significant development to facilitate the optimization of hydraulic designs is the availability of reliable, variable speed motors. Particularly for pumps of low specific speed and inherently low efficiency, there is now the opportunity to operate super-synchronously with the corresponding improvements in efficiency.

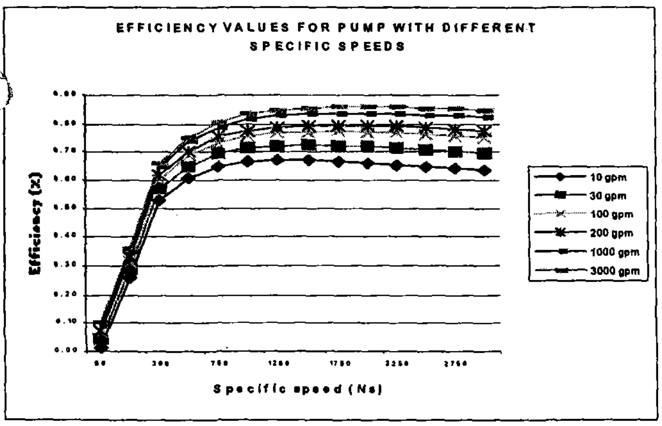

Fig. 5 show the "Maximum practically attainable efficiencies pumps dependent on specific speed and rates flow.

Mathematical model for these curves with the aid of regression. The efficiency η, curve via regression is approximated as [12]:

$$\eta = -8.84553 \times 10^{-3} + (7.9485 \times 10^{-2})Ns - (4.0913 \times 10^{-3})Ns^2 + (1.08499 \times 10^{-4})Ns^3 - (1.40755 \times 10^{-6})Ns^4 + (5.497 \times 10^{-9})Ns^5 + (4.07879 \times 10^{-11})Ns^6 - (2.66217 \times 10^{-13})Ns^7$$

And input power from torque and speed

$$P = T(2\pi N)/60 \text{ [Watt]} \qquad (4)$$

From the above formula/equation shaft parameters can be found.

b). Shaft

Referring to torque required from the shaft to the impeller the relationship is as follows,

$$d^3 = \frac{16}{\pi s_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (5)$$

Where,

S_s - Allowable

M_b - bending moment

M_t - torsional moment

K_b - fatigue factor (bending moment)

K_t - fatigue factor (torsional moment)

And rating life for ball bearings L, as give by the following equation:

$$L = (C/P)^3 \text{ million revolutions} \qquad (6)$$

Where,

P = the equivalent load

C = basic load rating

c). Casing

The effect of casing on the overall performance cannot be represented directly using design equations. There are some design guidelines which indicate the thickness of casing based on the pressure.

INITIAL RESULT AND DISCUSSION

In the present work to early steps in study have been carried out, which identifying design parameters and matrix interaction is mapping. From this mapping, the relationship between parameters that influence design a product performance can be determined easily based on optimum customer requirement as show Fig. 6. For instance, if customer gives specification in the form of head (m) or matrix interaction. As example, the interaction relationship between head (m) and D (diameter of impeller) are 0.5, because the relationship between two parameters is 0.5. Fig. 7 indicates the matrix interaction.

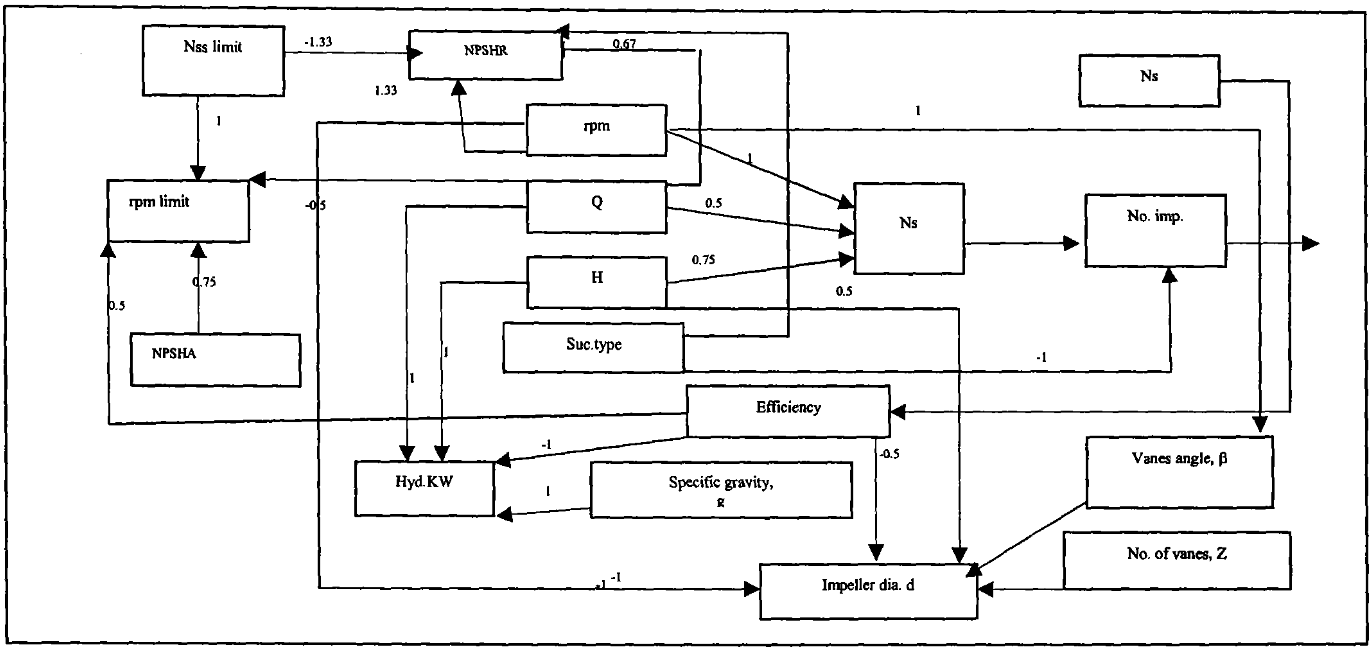

Fig. 6: Construction parameter digraph

		INPUT						OUTPUT						IMPELLER DIA.						
		N (rpm)	H(m)	Q(m^3/s)	sg	NPSHA	Nss	z	Ns	η	HydkW	BHP	NPSHR	Ns_{limit}	rpm_{limit}	cm3	u2	β	μ	d
INPUT	N(rpm)	X					1		1				1.33							-1
	H(m)		X						-0.75		1						0.5			
	Q(m^3/s)			X			0.5		0.5		1		0.67		-0.5					
	sg				X						1									
	NPSHA					X									0.75					
	Nss	1		0.5			X						0.75							
OUTPUT	z							X											-1	
	Ns	1	-0.75	0.5					X							1	-1			
	η									X	-1						-0.5			
	HydkW		1	1	1					-1	X									
	BHP											X								
	NPSHR	1.33		0.67			-0.75						X	-1.33						
IMPELLER DIA.	Ns_{limit}												-1.33	X	1					
	rpm_{limit}			-0.5		0.75								1	X					
	cm3								1							X	1			
	u2		0.5						-1	-0.5						1	X	0.5	-0.5	1
	β															-0.5	0.5	X	1	
	μ							-1									-0.5	1	X	
	d	-1															1			X

Fig. 7: Matrix interaction

CONCLUSION

The objective of this study is to identify module which with certain product design parameter variation change, performance can be increased. For now, pump design parameters have been identified and the interaction mapped.

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