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Selection of a Stirrer Drive Configuration Using Pugh Decision Matrix Methodology

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1. Abstract

The paper focuses on the application of the Decision Matrix methodology for selection of a gear unit for a stirrer drive. The stirrer drive is one of the most severe applications of a gear unit. The design of a stirrer drive is carried out based on information about motor features, nature of loading, stirrer constructive type, environment conditions and intensity of stirrer service, assembly requirements, interface with other system elements, et cetera.

Both technical and economical factors should be considered simultaneously. Usually, a design team considers several alternative technical and constructive solutions for a stirrer drive. The Decision Matrix method can assist in the building of a decision about best solutions.

Key words: decision making process, decision tree, weighted decision matrix, gear unit selection, stirrer drive.

2. Resumen (La selección de una configuración de la unidad de agitador utilizando la metodología de matriz de decisiones de Pugh)

El trabajo se centra en la aplicación de la metodología de la matriz de decisión para la selección de un engranaje de una unidad de agitador. La unidad de agitador es una de las aplicaciones más severas de un engranaje. El diseño de una unidad de agitador se lleva a cabo sobre la base de información acerca de las características del motor, la naturaleza de la carga, la tipología constructiva del agitador, las condiciones del entorno y la intensidad del servicio de agitador, los requisitos de montaje, la interfaz con otros elementos del sistema, etcétera.

Tanto los factores técnicos como económicos deben examinarse simultáneamente. Por lo general, un equipo de diseño considera varias alternativas de solución técnica y constructiva para una unidad de agitador. El método de la matriz de decisiones puede ayudar en la toma de una decisión acerca de las mejores soluciones.

Palabras clave: proceso de toma de decisión, árbol de decisión, matriz de decisión con ponderación, selección de unidad de marcha, unidad de agitador.

3. Introduction

Agitating is a mechanical process in which one or more fluid components are brought together in order to create a uniform distribution of fluid, solid and gaseous substances.

Areas of application of stirrers are chemical industry, polymers and plastic, pharmaceutical and cosmetics, bio-technology, varnishes and paints, desulfurization, energy, construction materials, water treatment, refinery installations, pulp and paper, mineral processing and other industries and activities.

Depending on the application, the speed can vary from very slow (< 1 rpm) to high speed (> 100 rpm).

A stirrer contains a driving unit, a rotating shaft with impeller, a holding vessel, a baffle plate, an internal flow created by impeller and a mixed medium.

The mechanical design of stirrers presupposes several arrangement variations [1]:

- top entry,
- side entry,
- bottom entry.

The stirrer can be horizontal or side entry.

The stirrer design depends on tank process differentiation:

- open tank processes,
- closed tank processes.

Open tank is typical for processes using oxygen from ambient or purely physical processes, for example, aerators in waste water treatment, hydrometallurgy, etc. Usually open tank processes do not require any special sealing system.

Closed tank is typical for chemical, biochemical and physical processes, where gases exchange with ambient is not allowed, due to danger of the medium or specific requirements of the process [2]. Closed tank processes are, for example, hydrogenation, flue gas desulphurization, polymerization, etc. Usually closed tank processes require special sealing between ambient, stirrer shaft and vessel.

4. Gear unit selection

The principal task of gearboxes for stirrer and mixer is to transfer the rotating energy by means of torque and speed via the stirrer shaft and impeller to the mixed or agitated medium.

One of the key parameters for the mixing or agitating process is the power which has to be supplied to the product via the impeller.

Even small deviations in required power or speed can cause big deviations in the process.

A mixer impeller generates axial and radial loads on the mixer shaft. Depending on the support of the mixer shaft, the gearbox has to take these loads more or less significant.

Radial loads are a result of an unbalance of hydraulic forces on the impeller blades. The radial force is rotating with the impeller.

It is important to predict the radial force that is function of the [2]:

- geometry of the impeller,
- speed,
- effective diameter of the impeller,
- density of the medium.

The gearbox has to adapt to impeller geometry and special needs.

The procedure for the project planning of an industrial gear unit begins with drive data selection. The more important data are ambient conditions, driven machine functioning on low and high stages, load characteristics on low and high stage functioning, special gear unit requirements, type and design, service factor, mounting and connection to driven machine [3].

Then gear unit selection process goes through calculation of gear ratio, calculation of input power, specification of gear unit size, reduction ratio and direction of rotation under load (with reversing direction of rotation or no), calculation and specification of permitted peak load, calculation of thermal rating and decision about any external cooling, checking of the occurring external radial and axial shaft loads.

The next step is a selection of connection to the motor, of alternative sealing systems, if required, of cooling and pressure lubrication components, if required, of monitoring functions and instruments, if required.

Finally, is done a checking of all defined requirements.

5. Decision matrix

Decision Matrix is one of the simplest decision making techniques. Invented by Stuart Pugh the Decision Matrix Method, also called Pugh Method or Pugh Concept Selection [4], is a quantitative technique used to evaluate, compare and rank the alternative multi-dimensional options of a technical solution set. A Decision Matrix Methodology contemplates a definition of evaluation attributes and their weight, a calculation of scores and an establishment of rankings among the considered technical solutions.

The rows and columns of the table correspond to judgment criteria and alternative options, respectively. It is possible to extend the options further through a brainstorming exercise. The selection criteria for judging the options can be various kinds of costs or losses, as well as benefits and so on. The relative importance of each criterion is weighted based on team feeling. An analysis of a Decision Matrix allows the identification of components and factors with highest influence on results.

The solution with highest score is selected as the better one. A Decision Matrix Methodology is used by several branches of engineering [5]. Development of mechanical engineering design, production process planning and operation programming, all require the use of techniques for evaluation and comparison of different possible technical and organizational solutions.

This paper intends to propose a conceptual model that explores the use of Matrix Decision techniques for selection of a design arrangement for a stirrer drive.

Four alternative drive configurations are considered [1]:

1) Configuration with two internal bearings (without external bearing), with rigid coupling between the gearbox shaft end and the stirrer shaft (Fig. 1).

2) Top configuration with two internal and one external bearing, with rigid coupling between the gearbox shaft end and the stirrer shaft (Fig. 2).

3) Bottom configuration with two internal and one external bearing, with rigid coupling between the gearbox shaft end and the stirrer shaft (Fig. 3).

4) Configuration with two internal and two external bearings, with elastic coupling between the gearbox shaft end and the stirrer shaft (Fig. 4).

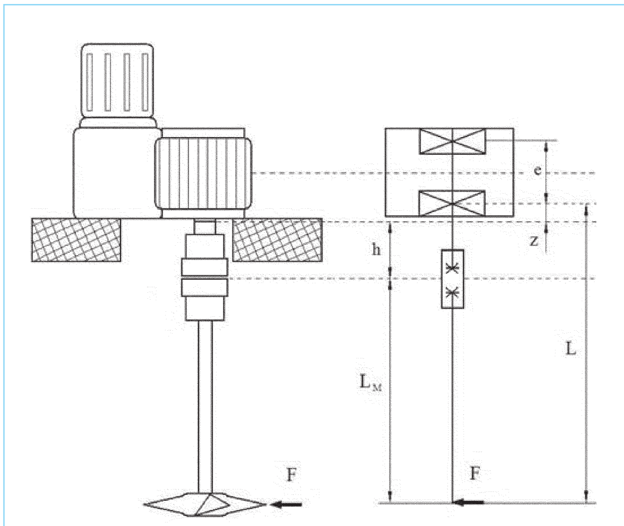

Fig. 1. Configuration 1.

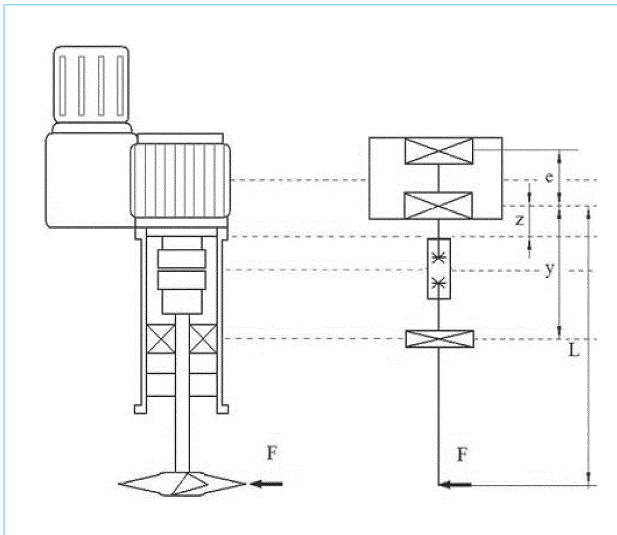

Fig. 2. Configuration 2.

The first step is an identification of evaluation attributes [6]. Established evaluation criteria are the following:

1. Component costs.
2. Assembly time.
3. Maintenance costs.
4. Occupied space.
5. Interface with another involved equipments.

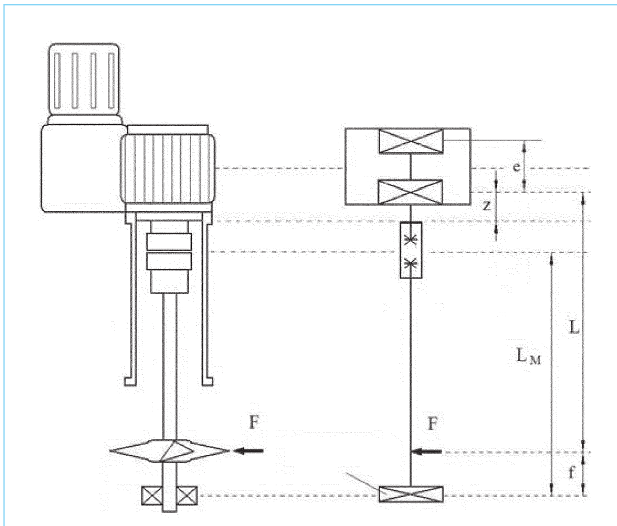

Fig. 3. Configuration 3.

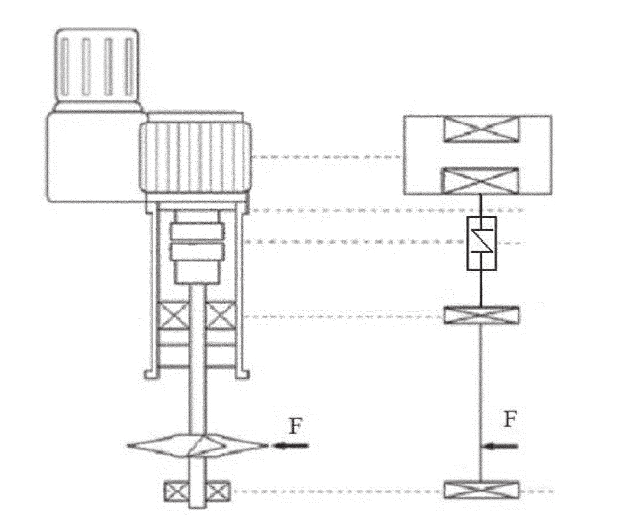

Fig. 4. Configuration 4.

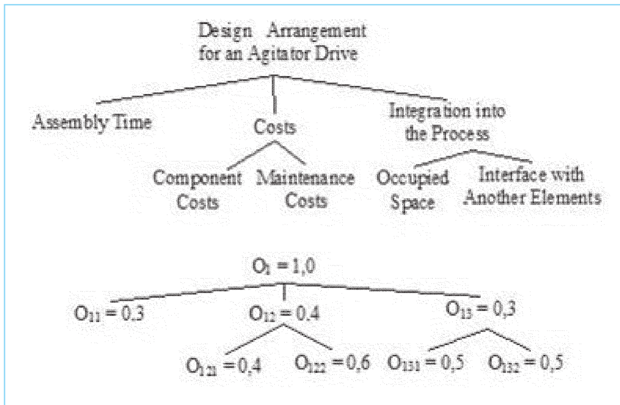

Fig. 5. Hierarchical objective tree for a stirrer drive design arrangement.

Then weight factors for each evaluation criteria are determined. For this purpose, Decision Matrix Methodology suggests a construction of a hierarchical objective tree. Fig.5 shows the hierarchical tree.

The weight factor of each criterion is obtained by multiplication of the weights going through correspondent tree branches from bottom to top [6].

Eq. (1) presents the calculation of weight of criterion "component costs".

$$O'_{121} = O_{121} \cdot O_{12} \cdot O_1 \quad (1)$$

Eq. (2) presents the calculation of weight of criterion "assembly time".

$$O'_{11} = O_{11} \cdot O_1 \quad (2)$$

Eq. (3) presents the calculation of weight of criterion "maintenance costs".

$$O'_{122} = O_{122} \cdot O_{12} \cdot O_1 \quad (3)$$

Eq. (4) presents the calculation of weight of criterion "occupied space".

$$O'_{131} = O_{131} \cdot O_{13} \cdot O_1 \quad (4)$$

Eq. (5) presents the calculation of weight of criterion "interface with equipments".

$$O'_{132} = O_{132} \cdot O_{13} \cdot O_1 \quad (5)$$

A 5-point scale (0-4) or an 11-point scale (0-10) can be used for evaluation of the score for each drive configuration for each criterion [6]. A 5-point scale (0-4) is used in this paper.

The rating for each drive configuration is obtained by multiplying the score by the weighting factor.

The overall rating for each drive configuration is the sum of these ratings.

Table 1 presents the weighted decision matrix.

Table 1. Weighted decision matrix for a stirrer drive design arrangement.

Design criterion	Weight	Configuration 1		Configuration 2		Configuration 3		Configuration 4	
	factor	Score	Rating	Score	Rating	Score	Rating	Score	Rating
Component costs	0.16	4	0.64	3	0.48	2	0.32	1	0.16
Assembly time	0.30	4	1.20	3	0.90	3	0.90	2	0.60
Maintenance costs	0.24	4	0.96	3	0.72	2	0.48	1	0.24
Occupied space	0.15	4	0.60	3	0.45	2	0.30	2	0.30
Interface with another elements	0.15	4	0.60	4	0.60	4	0.60	4	0.60
Total (overall rating)			4.00		3.15		2.60		1.90

6. Conclusion

Using Decision Matrix Methodology, a definition of a set of attributes is subjective. The final results depend to a great extent on a subjective distribution of attributes weights. The methodology has not any analytical tool for an analysis and validation of selected attributes or their weights. All weight factors are interdependent. The interdependence gets worse while the objective tree has more hierarchical levels [7].

In spite of the disadvantages, the decision matrix based on weighted sum of attributes can be a useful tool for decision making process. The matrix analysis can suggest additional study or call into question the validity of information and decisions.

Decision Matrix Methodology could be useful for selection of a gear unit for a stirrer drive. A final decision about the solution to be adopted must take into consideration organizational difficulty and specific requirements of the process.

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