APPLICATION OF RADAR CHART IN THE SELECTION OF MATERIAL FOR CLUTCH PLATES

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Abstract


Article deals with the choice of material used for manufacturing of clutch plates using graphical analysis. For analysis of used materials and specified parameters were chosen method of radar chart. Radar chart shows visually and quantitatively individually parameters used for the selection of material. The correct selection of the material has effect on the effectiveness and efficiency of manufacturing of clutch plate.

Keywords: radar chart, clutch, yield strength, ultimate strength, elongation, hardness

INTRODUCTION

Clutch disc is a part of clutch kits, whose function is the transfer of mechanical driving forces between the engine and other components. Clutch plates and clutch are used in automotive, engineering and aviation industries.

Clutch Disc is an element which is an integral part of every manual and automatic transmission. Without this component, the car does not move easily. Probably neither needless to say how important it is to have the clutch and all its components in good, driving satisfactory condition. In short, the clutch is designed to carry all the power produced by the engine to the front, rear or both axles (FWD, RWD, AWD), i.e. for the needs of propulsion (Matisková, 2012, 2013a).

The materials used in the manufacture of clutch components must be long-lasting, high-quality, since the coupling is one part of the whole machinery rental, which is loaded and used the most. Therefore, it is important to address this important innovation component connector’s particular material from which it is produced. One of the ways to restore the activity Sprocket is its renovation (Fig. 1), but it is easier to avoid this method of saving this element, finding better quality and longer-lasting material (Matisková, 2013b).

Verification state of organizations in the field of business economics can be understand like safety audit. Results of the verification are recorded by different methods. Manufacturing process and procedures can be assessed not only on the basis of the audit, but also by indicators of process capability $C_p$ (characterizes the variance of process) and $C_{pk}$ (characterizes the position of process in tolerance field. The manufacturing process shall be considered as qualified if the prescribed values of capability indexes are abided (Hrubec, 2001; Kredatusová et al., 2010; Lestyánszka, 2009; Konstanciak, 2012).

Graphical methods are widespread in statistics, because they are transparent and easily interpretable. Graphic display is especially important for transparent data analysis and understanding the relationship between individual variables (Tague, 2005).
A radar chart is a graphical method of displaying multivariate data in the form of a two-dimensional chart of three or more quantitative variables represented on axes starting from the same point. The relative position and angle of the axes is typically uninformative (Nenadál, 2004).

The aim of this study is comparison properties of the supplied material that are used in the manufacture of the clutch plate with ideal properties of material. Subsequently, we choose the most suitable material for use in the manufacture, thus leading to a reduction the number of disagreements of final product, pressing machine downtime and tool wear. Using worn cutting tools in the production process causes higher surface roughness $R_a$ of the machined part, which results in lowering production accuracy (Votava, 2013a). Surface quality $R_a$ likewise influences not only further production technologies and but also an anchoring profile of an anticorrosion coating (Votava, 2013b). With the proposed solution, we increase efficiency and effectiveness of pressing clutch plates.

**MATERIALS AND METHODS**

Radar chart was applied to manufactured component (clutch plate Fig. 1) which is currently manufactured from materials with different parameters specified in the Tab. I. Component is manufactured in the organization Miba Steeltex Ltd.

In the analysis can be used the quantity of parameters, however the radar charts are effective when using a limited number (no more than 8) (Plura, 2001).

Procedure of designing radar chart:
1. To determine variables that will be plotted and compared in the radar chart in the selection of the material. For determining variables can be used brainstorming, affinity diagram or Pareto analysis which is normally used for examine possible causes of disagreements.
2. To define intervals of values for each criterion. For each criterion, determine the indication of value intervals from 1 to 5, in ascending order of selected intervals.
3. To draw chart, 360 degrees divided by the number of criteria that determine angles between rays. To draw individual indications (1–5) belonging to interval of values on rays, and to connect the dots with lines.
4. To plot graphs separately for each material and ideal (the most suitable) material (i.e. 8 graphs).
5. To record the obtained values of indications and ideal (the most suitable) value of indications for each ray (to plot 2 points on each ray). Connect individual points according to the relevant materials.

**Interpretation of the Radar Chart**

The difference between values marked of individual materials and required values on each ray is a gap between the ideal and the actual. Parameter with the largest gap (deviation) usually requires an immediate attention. When using the charts is needed to avoid display that can potentially distort visual perception. Simple charts are the best.

**RESULTS AND DISCUSSION**

After the execution of brainstorming, we selected and set intervals of physical variables for used materials, i.e.: yield strength, ultimate strength, elongation and hardness. We prepared a table of intervals for the individual parameters of the material (Tab. II).

![Clutch plate](image1)

1: Clutch plate

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Material No. 1</th>
<th>Material No. 2</th>
<th>Material No. 3</th>
<th>Material No. 4</th>
<th>Material No. 5</th>
<th>Material No. 6</th>
<th>Material No. 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength $R_{eff}$</td>
<td>511</td>
<td>452</td>
<td>496</td>
<td>428</td>
<td>402</td>
<td>444</td>
<td>401</td>
</tr>
<tr>
<td>Ultimate strength $R_m$</td>
<td>688</td>
<td>693</td>
<td>688</td>
<td>666</td>
<td>717</td>
<td>687</td>
<td>701</td>
</tr>
<tr>
<td>Elongation $A_5$</td>
<td>28.4</td>
<td>32.4</td>
<td>30.6</td>
<td>31.6</td>
<td>35.2</td>
<td>32.2</td>
<td>37.3</td>
</tr>
<tr>
<td>Elongation $A_{80}$</td>
<td>19</td>
<td>20.7</td>
<td>19.8</td>
<td>20.8</td>
<td>22.7</td>
<td>20.8</td>
<td>23.5</td>
</tr>
<tr>
<td>Hardness $HB$</td>
<td>217</td>
<td>216</td>
<td>217</td>
<td>196</td>
<td>216</td>
<td>214</td>
<td>214</td>
</tr>
</tbody>
</table>
We made a table of intervals for individual values of physical variables (Tab. III) with the respective markings (1 to 5). The table contains the following columns:

The first column indicates marking of variable. Marking range of variables was determined in the range from 1 to 5 (dimensionless number), where 1 represents the lowest value of individual variables and 5 represents the highest value of variables.

The following columns represent the different intervals according to selected parameters. According to the Tab. III we transferred the individual parameter values of used materials with appropriate markings from 1 to 5. The same markings we applied for required (ideal) material from Tab. II. As follows, obtained data were written down into Tab. IV, from which data were used for the construction of radar chart Fig. 2 to 8.

**Evaluation of Radar Chart**

In the evaluation of radar chart, we concluded that delivered material has different physical parameters. Materials No. 1, 3 and 7 are similar only in one of required parameters with ideal (required) characteristics that are defined in the Tab. II. In two cases, it is ultimate strength $R_{m}$ and in one case, it is hardness $H_B$. Material No. 5 does not coincide in any of required parameters, and the manufacture of clutch plate causes the greatest probability of disagreement occurrence. Material No. 2 coincides in two required parameters i.e. $R_m$, ultimate strength and elongation $A_5$, Material No. 4 coincides in two required parameters i.e. yield strength $R_{eh}$ and elongation $A_{50}$. Delivered material No. 6 coincides in four of five required parameters, i.e. yield strength $R_{eh}$, elongation $A_5$ and $A_{50}$ and hardness $H_B$. According to the results from this analysis, Material No. 6 has proved to be the most suitable
for the process of pressing clutch plates, regard to reported parameter values which most closely approximates to ideal set parameters.

**Recommended Measures**

On the basis of analysis results we have done measures which led to clarify the conditions for supplying material for the manufacturing process of clutch plates. Supplier is obliged to supply the material in required parameters according to Tab. II which represent material No. 6 as the most suited one. Individual parameters will be checked upon delivery of the material, thereby avoiding the possible occurrence of disagreements during the manufacture of clutch plates, respectively higher tool wear.

**CONCLUSION**

A part of improving process design must include an evaluation of unavoidable hazards and unavoidable risk arising from proposed solutions in determined operating and usage conditions, assessment of the risk when using them and design of protective measures against these hazards (Burda et al., 2010; Hrubec et al., 2009; Lestyánszka, 2012; Ingaldi et al., 2013).

The main aim of this article was to determine parameters of used material in the manufacturing process of clutch plates. On the basis of set (ideal) parameters to evaluate delivered material and to choose from them a material fulfilling the specified intervals in Tab. II. Analyses shows that only one material – material No. 6 fulfils the specified conditions. This knowledge led to an agreement...
with a supplier about compliance set parameters of incoming material which influences the overall efficiency and effectiveness of the manufacturing process for clutch plates.

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REFERENCES


LESTYÁNSZKA (ŠKŮRKOVÁ), K. 2012. The statistical regulation of the turning process. Research papers Faculty of Materials Science and Technology Slovak University of Technology in Trnava, 20(Special Number): 81–85.


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