



## Materials selection for a cooling plate using control area diagrams

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### ABSTRACT

Merit indices are used to rank materials and are of fundamental importance in materials selection. Traditionally, merit indices have only been available for elementary design cases. In the present paper merit indices are generalised to cooling systems where heat flow and strength are design criteria in a materials optimisation framework. A cooling tube and a cooling plate are considered. A new concept, merit exponent is used that is related to the merit indices. A definition of the merit exponent is given also for cases with many design variables. In each design case a number of merit exponents are involved. It is a non-trivial task to identify which they are and when each of them is applicable. For this purpose control area diagrams (CAD) are used. A CAD is a diagram with the controlling properties on the axes, and areas where one or more constraints are active. For the cooling systems the controlling properties are heat conductivity and strength. The active constraints define the relevant merit exponent. The constraints involve the controlling properties and geometrical variables. Principles are established for how to set up the CAD and to derive the merit exponents.

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### 1. Introduction

Traditionally the selection of materials in mechanical design is often made in the following way. One chooses between a few materials which have been used for similar situations before. This often leads to a conservative choice and one also misses newly developed materials which may be suitable for the new modified situation. A small change in the design of the component can be crucial since the present material may no longer be the optimal one. This situation may be even more critical if the environment is changed which could lead to failure if the same material is used [1]. Therefore a systematic procedure is advantageous when one is selecting a new material for a product. One such technique is materials optimisation that is a part of structural optimisation with special focus on the selection of materials [2–7]. The selection of materials for simple components is discussed in many textbooks, see for example Ashby's book [8]. The procedure for materials optimisation in mechanical design is divided into three parts, sifting, discriminating search and optimising [9]. In sifting, materials groups that are of interest for the application are identified. In discriminating search or deselection, materials that do not satisfy some basic requirements for example concerning manufacturability are eliminated. The remaining materials that should be possible to use are ranked in the optimisation part. In the present paper only the optimisation part will be considered.

Aluminium alloys are often used in cooling systems due to their high specific strength in combination with a good heat conduction capacity. Applications of cooling systems can be found in vehicles, electronic systems and air conditioning devices. Typically many design variables are of importance in each individual application, and therefore it is important to have a systematic way to select the optimum alloy. One such systematic approach is to use merit indices and control area diagrams (will be called CAD through the paper) [10,11]. A CAD is a property chart where the geometry dependency is taken into account. The CAD gives information of what merit index that is active for a given combination of properties.

Merit indices were first introduced by Farag [12] and have since then used in many textbooks and papers, for a survey see [8,13]. The material with the highest merit index is the optimal material for that situation. Even in elementary design cases, several merit indices are involved and the relevant merit index must be identified before it can be used [1].

The concept merit exponent was formulated in [13]. In simple cases the merit exponent is the exponent in the merit index. In [13] the merit exponents were defined for the case with only one property constraints active. In the present paper the definition is generalised to situations where several property constraints are active. The merit exponent gives information on what geometrical parameter and property that is most beneficial to change for a given situation to improve the target function. The target function is the quantity to be optimised in a given design case. One common example is the weight of a component. The property that gives the

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