How a powerful material selection tool enables successful design at NCS Lab

Dr. Andrea Vecchi and Eng. Elisa Ferrari, NCS Lab, Via Pola Esterna 4/12, 41012 Carpi (MO), Italy

A Case Study |

NCS Lab is a private Italian company committed to supporting research and development. Its facilities and capabilities allow it to fulfill a complete development process from the idea to the finished product: concept, design, simulation, prototyping, testing, and validation. Automotive, healthcare, energy, packaging, and more industrial fields can take advantage of cutting-edge technical equipment and varied expertise.

NCS Lab puts into practice the definition of design given by Prof. M. Ashby: "Design is the process of translating a new idea or a market need into the detailed information from which a product can be manufactured".

Nowadays designers have access to several many software tools to support the "process of translating a new idea into a product". The best known are CAD / CAE software. Such software, however, cannot answer questions such as: "what is the best material for that product?" or "which material is the best performing / the cheapest / the easiest to find / the easiest to process?"

The answer to these questions is produced by the designer's experience. This is often limited and so risks excluding some potentially suitable candidates due to lack of adequate and easily accessible information.

> *"A time and money saving of 50%, or greater, in the prototyping and testing steps of the project... further money savings during the item lifetime."*

For this reason, NCS Lab decided to enhance its capabilities by adopting Granta's CES Selector™ as an additional software tool to support material selection. Its large database and versatile and powerful tools render it an invaluable aid for all the relevant activities of the company: project design, materials and manufacturing processes consultancy, supporting data for characterization, and failure analysis. Most of all, it allows a wide range of users with different skills to access, compare, and analyse materials data in a quick and consistent manner, saving time and reducing costly design iterations.

This case study shows how CES Selector has supported one of the routine projects at the NCS lab: the preliminary design of a medical device.

Preliminary design of plastic forceps for percutaneous dilatational tracheostomy

The goal was to re-design a pair of surgical forceps, to be used in the operation of percutaneous dilatational tracheostomy according to the Griggs technique, starting from the existing (metal) device-design.

The forceps that are currently used in this technique have existed for many years: metal replacement with a polymeric material would be welcome.

Defining the problem

The forceps that are currently used in this technique have existed for many years: they are made of a metallic material (stainless steel) and can be reused several times after sterilization. Though it is functional, there was a desire for improvement, considering that surgical instruments generally play a significant role in the success of a surgical procedure.

Assuming safety and reliability to be essential characteristics of the device, the final aim is to redesign the existing forceps, improving them from the points of view of lightweight, cost-effectiveness, and ergonomics. **In particular, metal replacement with a polymeric material would be welcome.**

The designer aims to identify the best solution that combines safety, functionality, ease of production, aesthetics and economy. He does that through various steps: the analysis of existing surgical instruments, the design of the new forceps (CAD), the choice of the best material that meets the requirements of the project (CES Selector), and the forceps performance simulation (FEA).

To make an appropriate material choice, when the purpose is replacing the currently used material (AISI 630 stainless steel, also known as 17-4 PH) with another one, a series of minimum requirements must be defined. These become the constraints of the material selection process. The new material must fulfill the following requirements: it must be appropriate for the medical use, fit for sterilization, strong enough for the working loads, and suitable for injection molding manufacturing process.

Selecting the right material

The material search starts with the 'universe' of polymers: among the 659 plastic materials listed in Granta's MaterialUniverse™ database, 512 fulfill the criterion of injection moldability, but only 30 also comply with the criteria of fitness for sterilization and availability of a medical grade conforming with USP Class IV and ISO 10993. Polymer families such as PA / PEEK / PEI / PES / PARA / PPO / PPS / PSU / PPSU / SPS / LCP generally reinforced with glass or carbon fibers, are among the complying materials.

Once this first screening of the materials to those that fulfill the constraints has been obtained, they can be ranked according to the project objectives. That is, they are classified on the basis of what property needs to be maximized (i.e., strength, thermal resistance, etc.) or minimized (i.e., mass, cost, etc.).

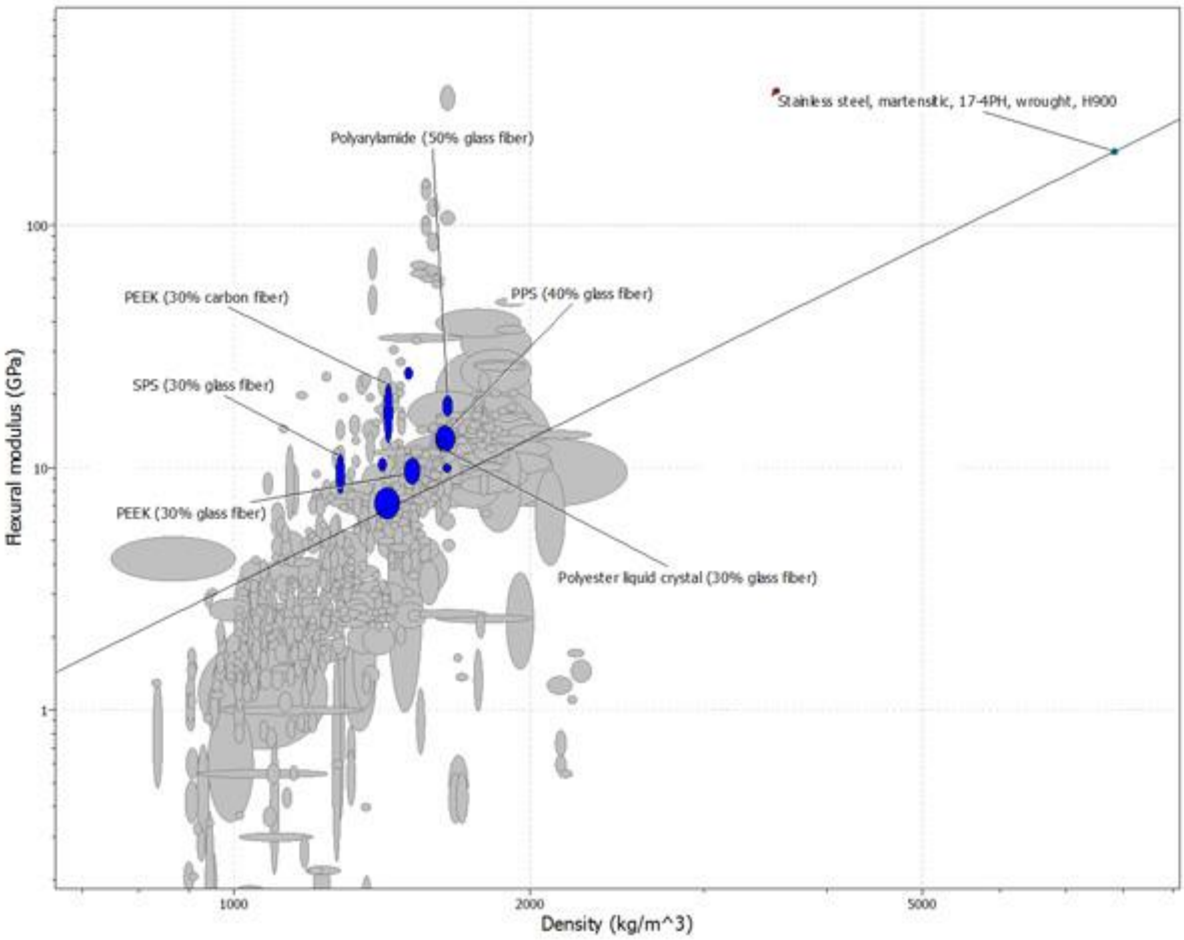

Figure 1: Stiffness-limited selection, minimizing mass : the line represents points with the same value of performance index. The highlighted materials are valid alternatives to steel 17-4PH.

The forceps are subjected to bending loads on each arm. Therefore, with regard to the mechanical and physical characteristics of the material, the flexural strength and the flexural modulus are the most interesting properties to the designer. Moreover, density is considered a priority as well, since minimizing the mass is a plus (with consequently decreasing costs, energy, and environmental impact).

It is well known that, for any given engineering problem, material performance usually depends on the combination of two or more properties. The mathematical function expressing this combination is known as a performance index.

In this particular case, CES Selector makes it easy to identify the performance indices for a stiffness-limited or strength-limited design, by minimizing the mass of the component treated as a beam loaded in bending with specified stiffness (or strength), length and shape, and with free section area.

The powerful graphical interfaces in CES Selector allow the designer to easily locate materials with a performance index equal to, or higher than, the steel taken as a reference. In Figures 1 and 2, the line represents points with the same value of performance index. The materials that lie on the line, or above it, are valid alternatives to steel 17-4PH. The list of materials that meet the requirements, then, further narrows from 30 to 10 options, including PEEK / PARA / PPS / SPS / LCP reinforced with glass or carbon fibers.

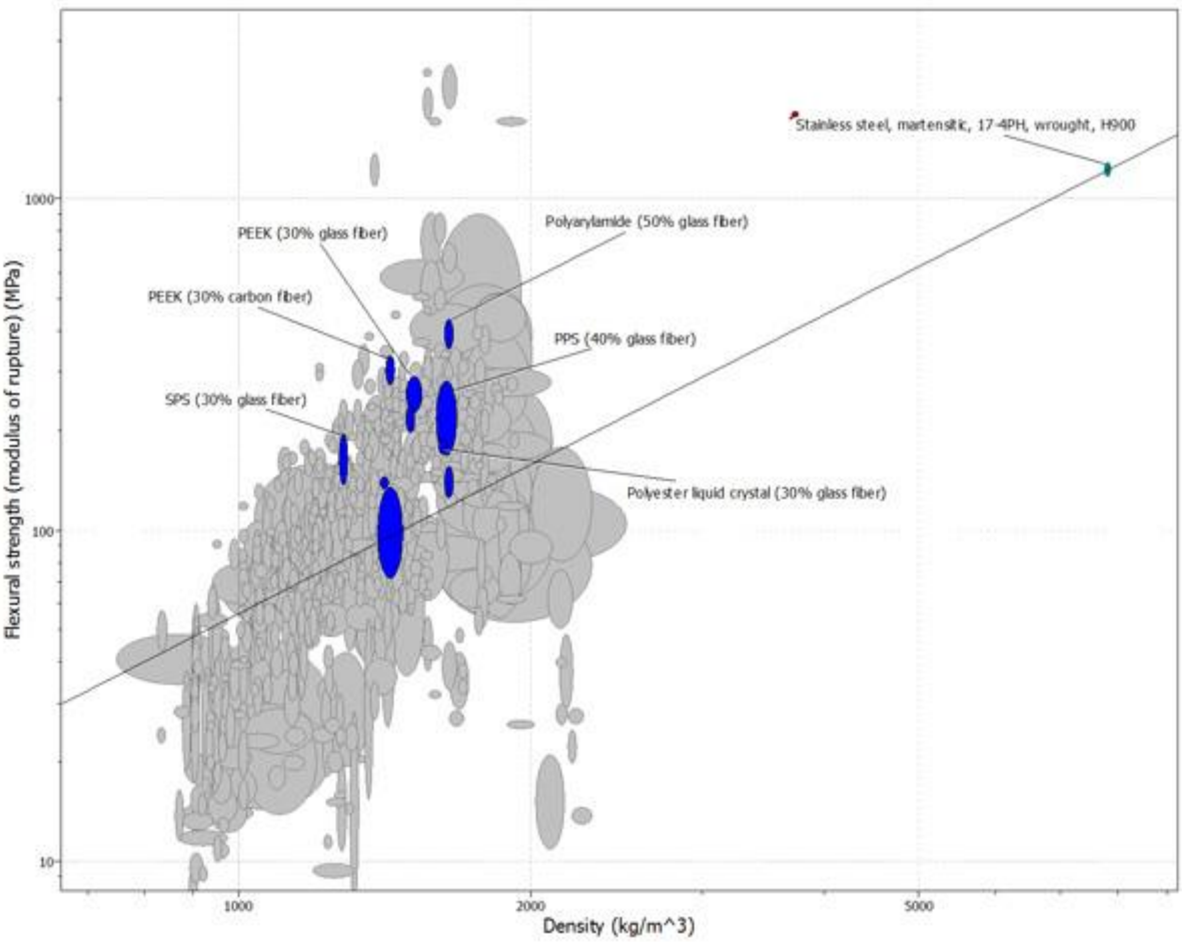

Figure 2: Strength-limited selection, minimizing mass: the line represents points with the same value of performance index. The highlighted materials are valid alternatives to steel 17-4PH.

The choice of the most cost-effective material is supported by graphically displaying the cost of each candidate. Figure 3 shows that the materials with a specific cost (i.e., cost per unit of mass) less than that of steel are PARA + 50% GF and SPS + 30% GF.

At this point, the detailed individual properties of the two materials can be studied. CES Selector provides a detailed datasheet for each one, containing the relevant information about technical specifications (mechanical, thermal and electrical properties, chemical resistance, etc.). That enables the designer to support the choice with specific data, including trade names and supplier references. In this way, it is possible to look for material availability, to verify prices, and to ask for detailed data sheets, molding guides, and certificates of conformity.

Following this rational selection process, the material of choice is PARA + 50% GF, in light of its superior mechanical performance. The material choice was then validated through FEM simulations, which also allowed the optimization of the forceps' geometry and ergonomics.

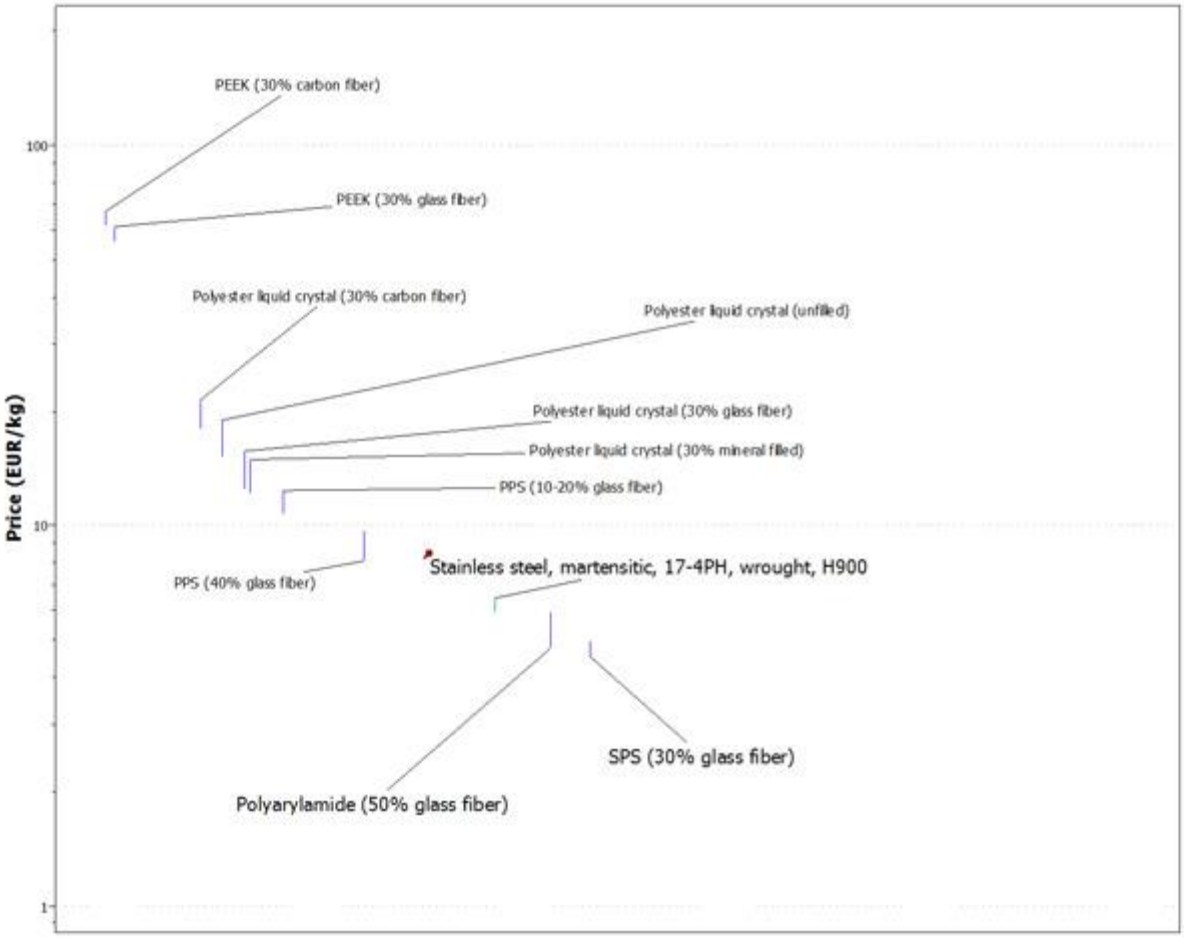

Figure 3: Cost ranking: the materials with a specific cost (i.e., cost per unit of mass) less than that of steel are PARA + 50% GF and SPS + 30% GF.

Conclusions

There are considerable advantages to approaching such a problem in this way. CES Selector allows the systematic selection of the material by using a method based on objective data, mathematical equations (performance indices) and an extensive database. This is essential to prevent numerous computational attempts with many different materials, minimizing the production of prototypes and the number of experimental tests: for this reason, it is estimated a **time and money saving of 50%, or greater, in the prototyping and testing steps of the project**. Moreover, the effective optimization of the material selection provides real innovation with regard to the project objectives and therefore brings enhanced performance, durability and visibility to the device, thus inducing **further money savings during the item lifetime**.

> *" the effective optimization of the material selection provides real innovation with regard to the project objectives and therefore brings enhanced performance, durability and visibility to the device, "*

The simplicity and versatility of CES Selector makes it a suitable tool for both materials experts and mechanical designers. The materials experts can find quick responses useful to expand and support their knowledge, while mechanical designers can immediately compare the potential of all classes of materials, not limiting their project with conservative choices dictated by tradition, so enabling the design of really innovative components from all points of view.