COLLIMATOR DESIGN FOR 35 G

The design principles of the late Wim van der Hoek, former Philips engineer and Eindhoven professor, are still current in high-tech systems engineering, including in the field of medical technology development. They are especially useful when high precision is required and conditions are challenging. This article presents a brief overview of the design philosophy, illustrated by an elegant example, from Van der Hoek's 'own' Philips; the design of a collimator, for a CT scanner, of which all parts are subjected to accelerations of 35 g.

MICHEL LOOS, ERIK MANDERS AND HERMAN SOEMERS

Wim van der Hoek (1924-2019) established his name in the 'precision world' with his work at Eindhoven University of Technology on design principles for precision mechanisms. However, he was also a Philips man in heart and soul and one of the founders of the Philips Centre of Manufacturing Technologies (*Centrum voor Fabricage Technieken*, CFT). Founded in 1968, the CFT played a leading role within Philips in the field of manufacturing processes and production mechanisation.

In the early days, Van der Hoek was one of the central figures in setting up the CFT and led the Mechanics and Mechanisms department. At that time, he already held the position of part-time professor and, in the form of lecture notes, started collecting examples for the design and calculations of cam-driven machines. Like no other, he was able to bridge the gap between academic knowledge of mechanical design and the daily Philips practice in the production mechanisation departments and later also product development. Scientific analyses were stripped down to manageable equations and insights that designers could use when making their many design choices.

For Philips, this meant that the development process for mechanical and mechatronic products and systems required fewer iterations and their behaviour (often in terms of dynamic and static accuracy) became much more predictable. Therefore, the required development effort

Dutch doyen of design principles

After the passing away of Wim van der Hoek, in early 2019, DSPE decided to publish a book about the Dutch doyen of design principles. The presentation took place on 18 November 2020, during an online Precision Fair event. The book (in Dutch) covers Van der Hoek's formative years, his career at Philips and Eindhoven University of Technology, where he developed his breakthrough ideas on achieving positioning accuracy and controlling dynamic behaviour in mechanisms and machines, and the reception and diffusion of his design principles. It concludes with his busy retirement years in which he continued to tackle – technical as well as social – design challenges, believing that technology should support people. The book (Figure 1) can be ordered via the DSPE website.

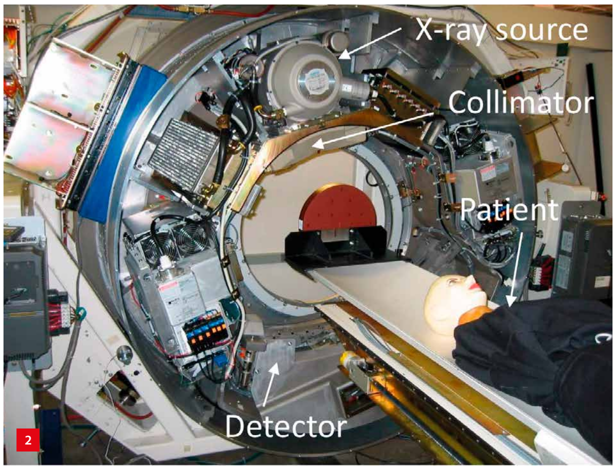
WWW.DSPE.NL

Lambert van Beukering & Hans van Eerden, "Wim van der Hoek, 1924-2019, A constructive life – Design principles and practical learnings between criticism and creation" (in Dutch), ISBN 978-90-829-6583-4, 272 pages, DSPE, € 49.50 (€ 39.50 for DSPE members) plus € 6.50 postage.

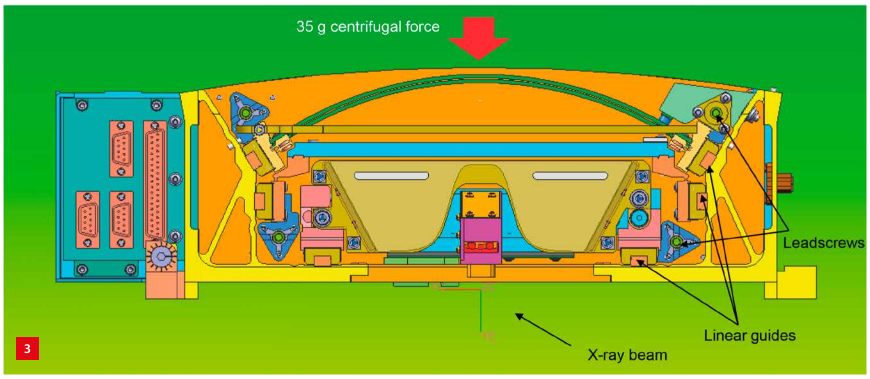
AUTHORS' NOTE

Michel Loos (senior designer), Erik Manders (senior architect mechatronics) and Herman Soemers (technology manager) all are associated with Philips Engineering Solutions in Eindhoven (NL).

m.a.d.loos@philips.com
www.engineeringsolutions.philips.com



CT scanner equipped with a bore through which the patient can move. The X-ray source and collimator are located on one side of the rotor and the detector on the other side.



Design of the collimator, with the curved shutter blades in the X-ray beam and the linear guides and drives just outside the beam.

decreased. And because the application of his insights made it clearer which tolerances really mattered, in many cases less precise parts – at a lower cost price – were needed.

The core of the Philips design philosophy is still based on thinking in degrees of freedom. The continuity of the application of these insights is not self-evident within a company such as Philips, which is in a continuous process of change with a large (international) influx and outflow of designers. Despite this – or perhaps because of it – within Philips, both at home and abroad, designers are still regularly trained in using the design principles. The importance of this philosophy, which has meanwhile been laid down in the textbook "Design principles for precision mechanisms", by technology manager Herman Soemers, cannot be overestimated.

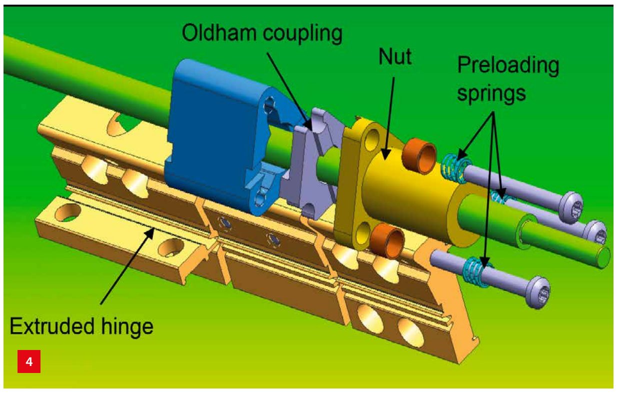
The Philips Centre of Manufacturing Technologies became Philips Applied Technologies in 2005 and evolved into Philips Innovation Services in 2011, recently renamed to Philips Engineering Solutions. Despite the changes, much was retained, such as working for a wide range of clients. Contributions to the design of mechanics and mechatronics range from consumer goods to large medical systems – and beyond Philips, especially the well-known high-tech for the semiconductor world. What all these applications have in common is that the design is very challenging and requires creative, new solutions, drawing upon the timeless design principles of Wim van der Hoek.

Collimator for a CT scanner

An elegant application of these design principles can be found in the design of a collimator for a CT scanner (Figure 2). This collimator (Figure 3) is intended to be able to adjust the shape and intensity of the X-ray beam. The unit includes moving shutter blades and filters, and sits directly behind the X-ray source; both modules are mounted on the rotor. This rotor has a bore through which the patient moves.
In modern systems, the rotor can rotate around the patient at a speed of up to 250 rpm. This results in centrifugal accelerations of approximately 35 g on all parts of the collimator.

Because the shutter blades have to block X-rays, they are made of a heavy material, such as lead or tungsten, which is very unfavourable for the forces on the linear guides and the construction. The linear guides are necessary to move the shutters and filters during operation. Since the beam must not be blocked by mechanics, these linear guides and also the components of the drive are located next to the beam. The need to drive well outside the centre of gravity, where very high g forces occur, while requiring a repeatability of the shutter blades in the micrometer range, made it necessary to remain rigorous in the application of the design principles. In addition, the cost price of the parts had to be kept low for this serial product. All-in all, this design assignment made considerable demands on the creativity of the designer.

In order to accurately introduce the forces on the collimator carriages, various parts are fitted with flexure hinges, leafsprings and sprits to correctly constrain the degrees of freedom. The production of hinges by means of wire-erosion was not an option here because of the desired cost price. Extensive use has been made of aluminium extrusion profiles; flexure hinges are immediately extruded and are therefore obtained – 'for free' – as a monolith. Simple milling operations are then sufficient to create decouplings in other directions.
Shutter blades and filters are driven via screw spindles with pre-tensioned plastic nuts. The spindles will bend as a result of g forces. To radially relieve each nut, it is secured via an axially preloaded Oldham coupling (Figure 4).
Here the shutter blades are not made of lead but of tungsten. This makes a separate 'supporting construction' (which would be necessary for the weak lead) superfluous. Because the blades have been given an arc shape, centrifugal forces are transmitted in the plane of the blade sheet and the



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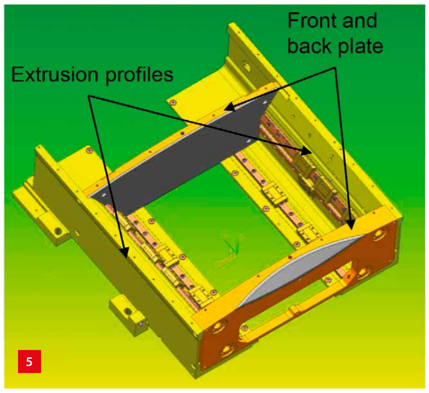

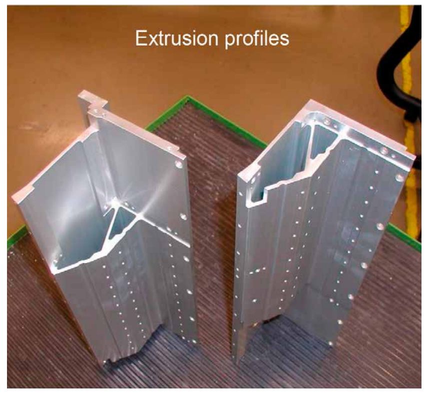

Design of the collimator frame according to the principle of the refrigerator vegetable drawer: tubular extrusion profiles with front and back plate make the frame a stiff assembly.

deformation of the blade is minimal. The curved blade construction makes parallel adjustment of both blades relatively easy. This is done by twisting the blade with the aid of a sprit, making use of the internal degree of freedom of the bent blade.

The open frame of the collimator is also largely made of extrusion profiles. In order to give this frame – in fact, an open box construction – the required high stiffness, the ‘principle of the refrigerator vegetable drawer’ has been applied (Figure 5). Box-shaped extrusion profiles with front and back plate make the frame a stiff assembly. Truly a ‘VanderHoekean’ solution.

The final realisation is shown in Figure 6.

Senior designer Michel Loos showing the construction of the collimator with two curved shutter blades.