Directed Variation®
Piston Ring CASE

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Introduction to directed variation

X	*the product, the process or service, the system, thing or article subject to study; mainly expressed in a noun. Examples: table, pen, car, bank, restaurant.*
function	*the purpose of X, it's useful action, what X **does** or **undergoes**, mainly expressed in verbs and related to the technologies. Examples: joining, cleaning, wearing, measuring.*
property	*a variable; its attributes, what X **is** or **has**, mainly expressed in adjectives and related to the sciences. Examples: hollow, smooth, transparent, strong, flexible.*
spectrum	*property spectrum, the variety, the range or scale in which a property is variable Examples: porosity, surface, flexibility, strength.*

property X => function

example
property = jointed
spectrum = flexibility
X = ruler
function = folding

e.g. A jointed ruler can fold.

The basics of directed variation® state a product property enables a function. The sum of all properties is called the *talent of the product*; it is what the product is able to do or undergo. It is defined by the precise points within a property spectrum (see Figure 1 green points). In the property spectrum porosity, figure 1 shows the property hollow. Hollow X has the talent to contain, insulate, enlarge, reduce weight, pass substance, filter, hold and absorb.
If the talent of the current product does not suffice the required client functions, properties need changing. Take grip or holding as a client requirement, the property smooth, can be varied along the surface spectrum to protruded =>holding. Alternatively the property linear can be varied along the shape spectrum to 3 D => holding.

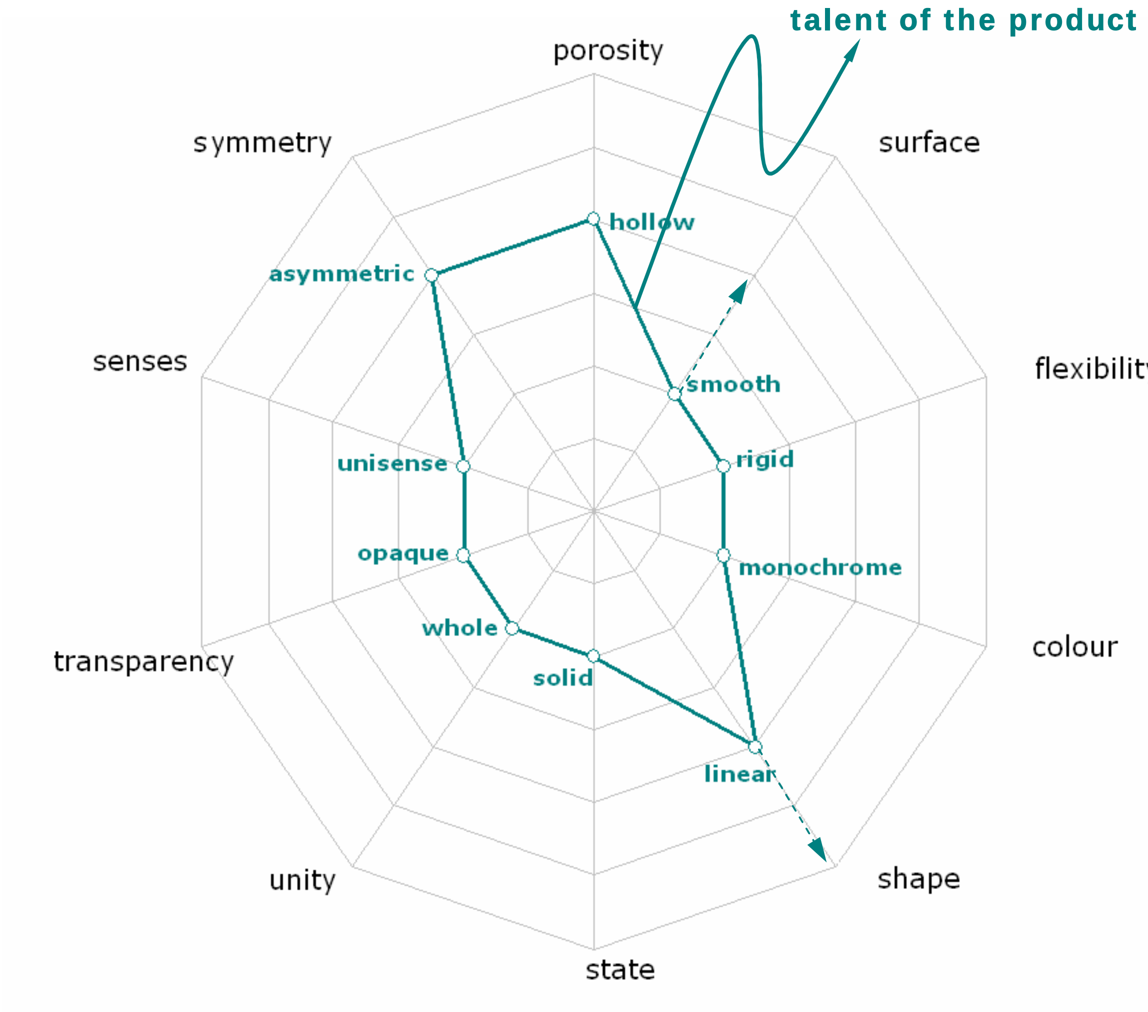
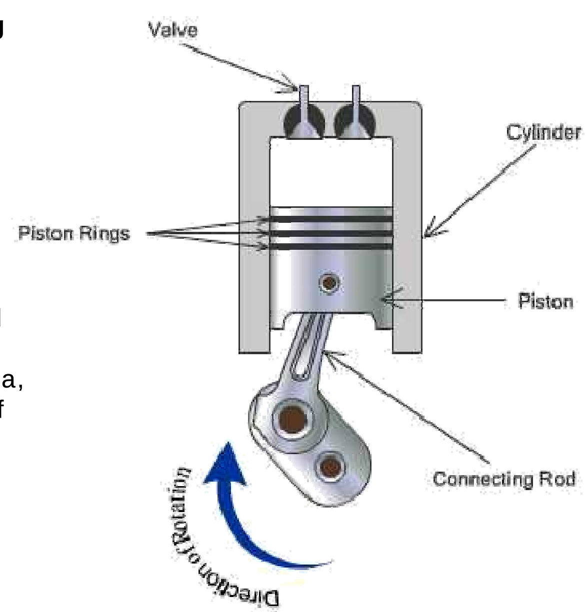


Fig. 1 Property Radar Plot

CASE: Directed Variation of the Piston Ring



All properties are for function. Looking at the case 'piston ring' all patents within the ECLA Code F16J9 were collected. The total of title, abstract, description and claims were analysed. The pool counted 2666 patents (over 1975-2005). Out of this pool, 367 unique adjectives were distilled, of which 70 proved useful. Fourteen useful property spectra were selected of which ten are shown in Figure 2. The adjectives are placed within the property spectra, with the frequency of use; i.e. 'hollow' is part of porosity spectrum, and occurred 173 times.

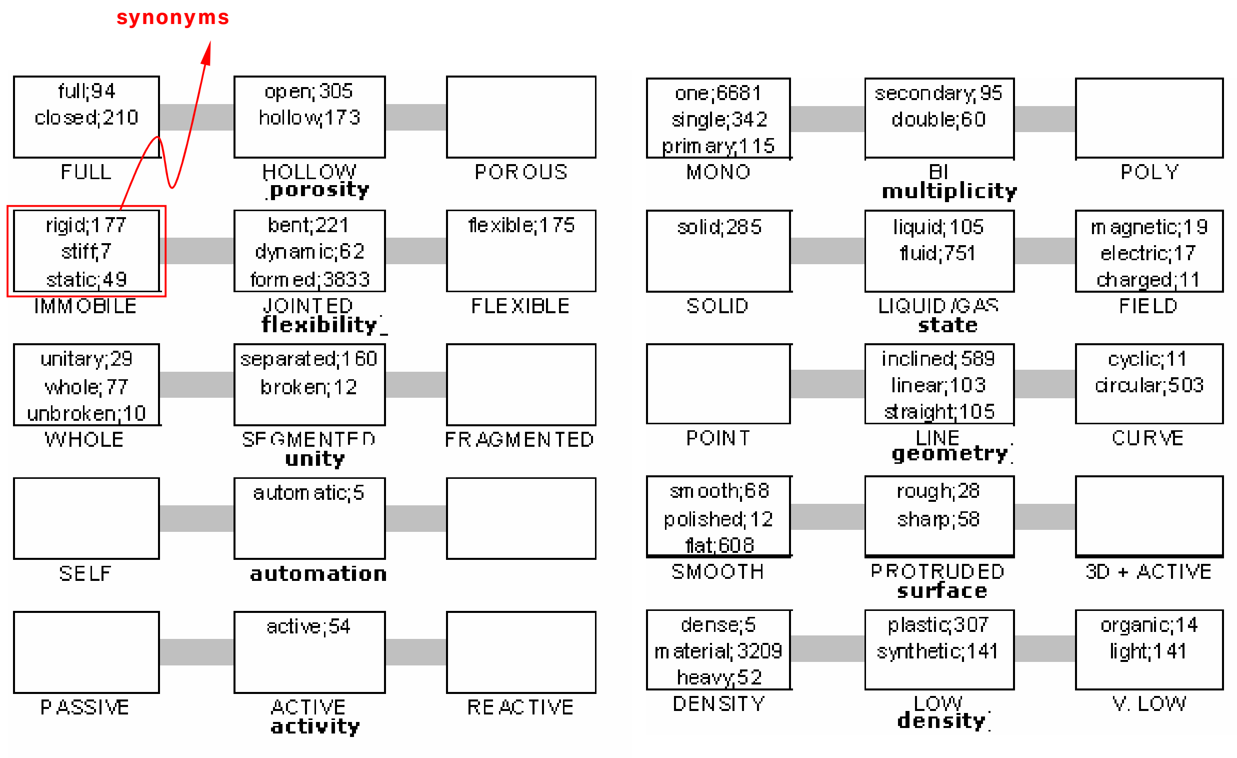


Fig. 2 Adjectives filling the property spectra of 10 properties

Within the pool of adjectives, *synonym* are clustered that relate a distinct property. They do represent differences in properties of a piston ring. These also include temperature, dimensions, speed and strength, which are not typically mentioned in triz-based trend tools. Figure 2 and 3 illustrates these property spectra.

This gives an overview on the patent activity of each property. Some properties are already applied multiple times, while other properties still stay unused. The white spaces coming out of the software are poly (multiplicity), 3D + active (surface), fragmented (unity), reactive (activity), porous (porosity). Poly looks interesting, is there an advantage of having more than 3 piston rings? Although surface is an important property to obtain a good seal with lesser friction/ heat, it isn't that much used for the moment. For oil rings segmented is already used. Is there an opportunity in doing the same for the other piston rings? As most of the material used is still passive, there is an opportunity in having a reactive piston ring.

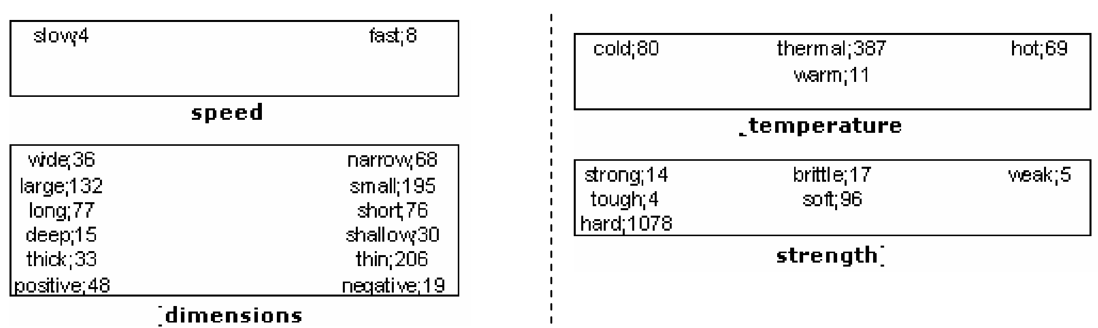


Fig. 3 Adjectives filling the variation spectra of 4 extra properties

Talent of the Piston Ring

The data of Figure 2 and Figure 3 allow constructing a property spectrum of the piston ring. This property spectrum represents some of the activity of design within the area of piston rings within the last 30 years.

Based on the most patented properties as shown in Figure 2 and 3, Figure 4 A and B illustrate a property plot of a piston ring. Note that the variations are defining an outer circle as well as an inner circle. The figure does not display none patented properties, although those are at least as important to consider in the creation of new designs.

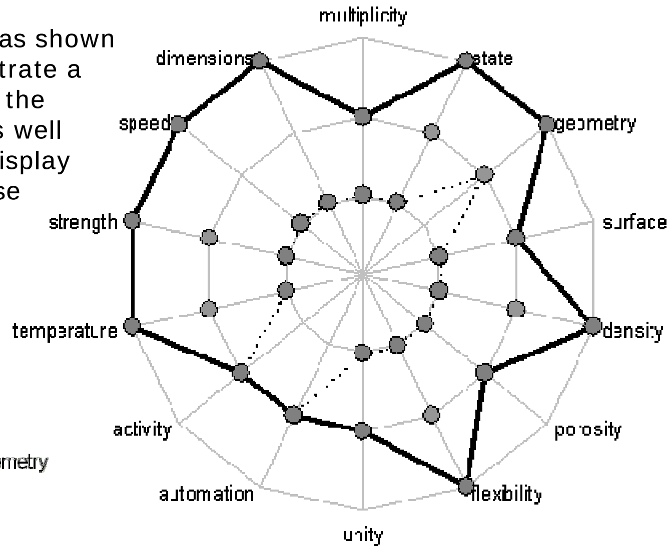


Fig 4.A. Property spectrum Piston Ring

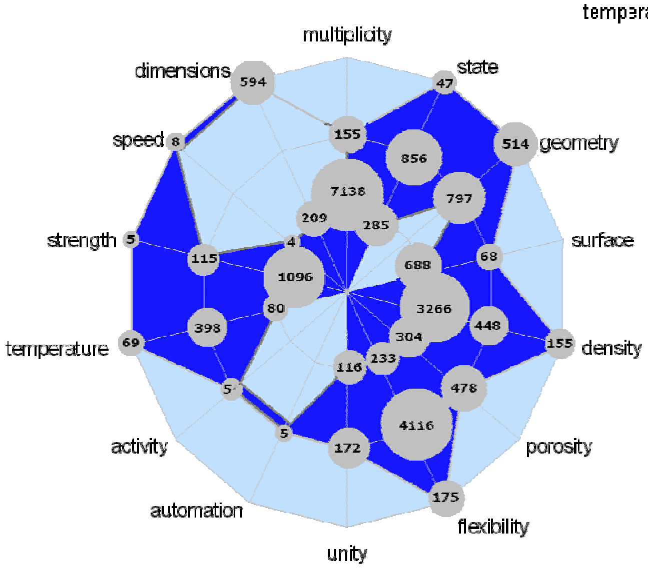


Fig 4 B Indicating the property occurrence

Figure 4 B depicts the occurrence of properties within the patent pool.
Some noise is experienced in the current graphs as the one patent can mention a property once or one hundred times. So, 'flexible' is mentioned 175 times doesn't mean there are 175 patents on flexible piston rings, as a patent mentions it more than once.

Figure 5 illustrates a selection of property variations over time. It shows that the properties flexibility, multiplicity, geometry, state become more and more used. This gives us a clear indication on what the industry is or isn't working on. Multiplicity here is overestimated as there are 3 piston rings.

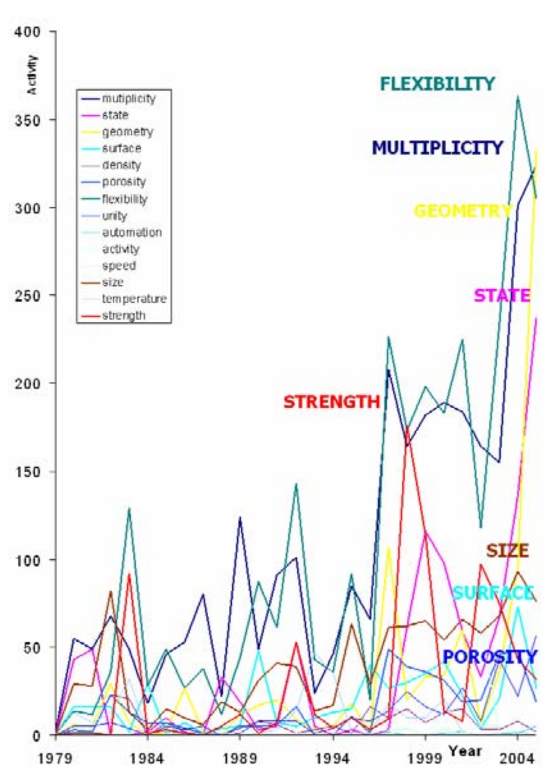


Fig 5. Property variations over time

Material Occurrence

By analysing adjectives, some indication of material use can be made. A material is often expressed as adjective, e.g. a plastic piston ring or a synthetic piston ring. Most materials however are nouns, e.g. a piston ring made of steel. A material search through the data gives Figure 6.

alloy	6840	S	799	Al	337	Ti	102	Tm	42	PPS	17
steel	4729	P	794	bronze	326	tin	98	Sm	42	mercury	16
chromium	3837	I	793	Y	314	calcium	90	Yb	42	Polymer	16
C	3535	Ni	737	manganese	288	Fr	86	Eu	42	Hg	16
iron	3438	cobalt	651	boron	277	Sn	73	Sc	38	Ar	14
aluminum	2880	PTFE	594	vanadium	262	silver	72	Tungsten	36	Pt	12
carbon	2681	W	583	O	254	Be	63	Pd	34	PAN	12
composite	2328	Mo	570	rubber	224	Er	59	Sb	33	Pm	10
resin	2031	U	535	K	210	Zn	55	Ca	32	Ag	10
B	1464	Mn	492	ceramics	181	Am	54	PFA	31	Argon	10
nickel	1316	H	471	Ce	164	Gd	51	Ra	29	Os	9
silicon	1222	Fe	461	hydrogen	163	Pr	50	Hf	29	Cl	9
F	1131	Cu	452	Mg	156	vapour	50	PS	28	Selenium	9
Cr	1083	lead	451	Nb	154	Ho	48	Cd	24	Polyester	8
plastic	1070	V	412	PEEK	152	Dy	48	beryllium	22	Ru	8
ceramic	1023	N	405	magnesiun	141	Nd	47	Rh	18	Silicone	8
chrome	898	Co	393	zinc	134	Au	46	Nitrogen	18	PI	8
titanium	897	polytetraflu	362	Zr	117	Tb	45	Re	17		
copper	848	CrN	361	diamond	103	Ta	45	Ge	17		

Fig 6. material occurrence in piston ring patent pool

The difficulty with piston rings is that a large range is covered; first there are 3 types of piston rings:

- Compression ring,
- Scraper ring,
- Oil flow ring.

Second there is the material of the piston ring versus the coating of the piston ring. But taking this in account and comparing the results known by the art versus the software generated data, similar materials are obtained Alloy, Steel and Iron .

For coatings for both searches chromium is the most used coating material, together with carbon, titanium. An important coating that isn't founded is nitriding, as it is not an adjective/ noun.

Figure 7 (right) plots the material occurrence over time. It is only a selection of the lit in Figure 6. and shows that the discussions in patents on nickel and cobalt were quite popular in the 70ies where as recently the main topics such as resin or chromium coatings have taken over.

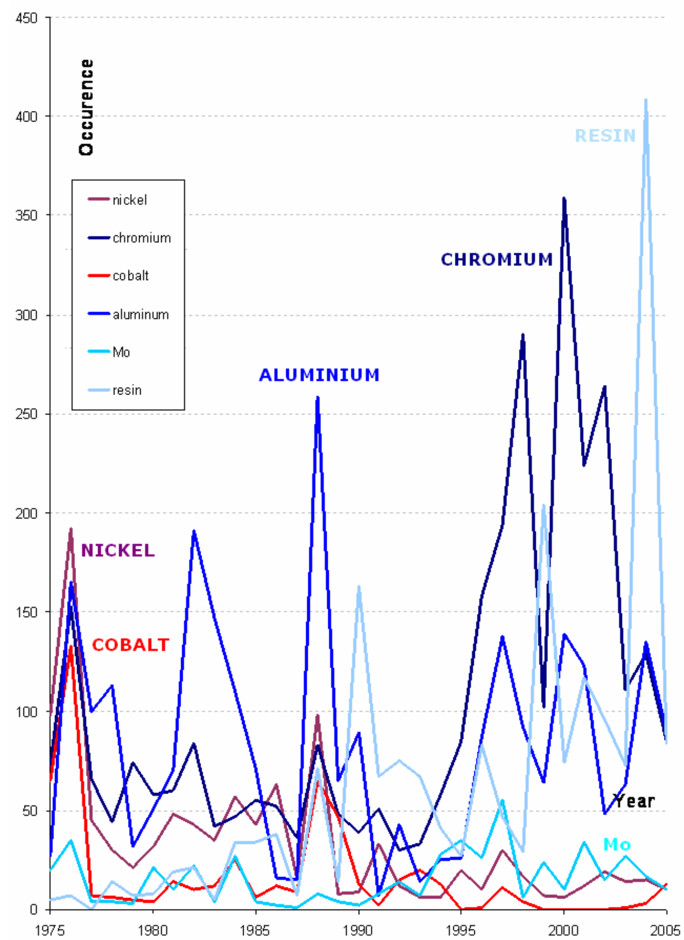


Fig 7. Material Occurrence over time (selection)

Connecting to functions

Cross-referencing the verbs of the patent pool with the lit of functional verbs out of the CREAX function database (http://function.creax.com) delivers 23 verbs shown in Figure 6A. 6B is a wider selection of functional verbs. Both lists represent actions that have importance in the area of piston rings.

A

produce	969	absorb	94	destroy	28
separate	884	connect	85	freeze	23
move	789	join	80	extract	16
contain	303	locate	70	condense	10
remove	280	adhere	65	preserve	9
hold	251	filter	56	dissolve	5
melt	119	lift	53	amplify	2
float	95	orient	35		

B

wear	7737	lock	354
cast	2853	fracture	352
cut	2832	transfer	350
strip	2639	charge	301
block	1353	scuff	262
exhaust	1220	crack	224
expand	547	carry	160
rotate	356	fill	156

Fig 7. Functional verbs distilled out of patent pool with number of appearance

Comparing the results known by the art versus the software generated functional verbs data, wear is in both cases the most important. That the software mentions cast is normal, because casting iron was used a lot as material. For the piston ring heat-resistance, peeling, friction, scuffing is also important, of which only scuffing is mentioned.

Property Spectra over Time

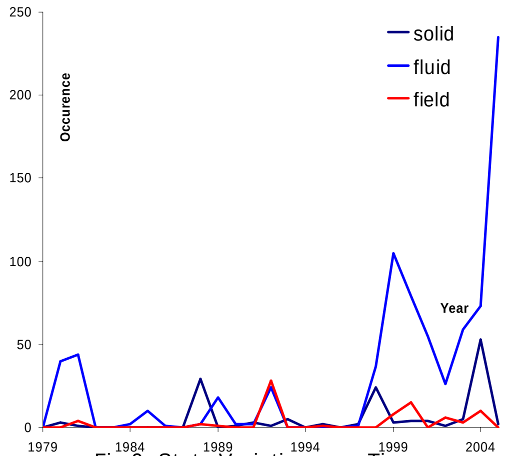


Fig 9. State Variation over Time

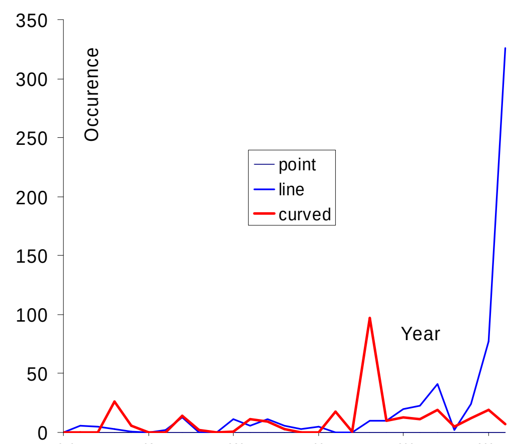


Fig 10. Geometry Variation over Time

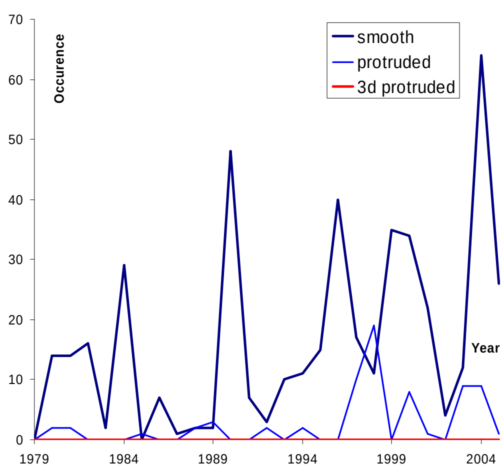


Fig 11 Surface Variation over Time

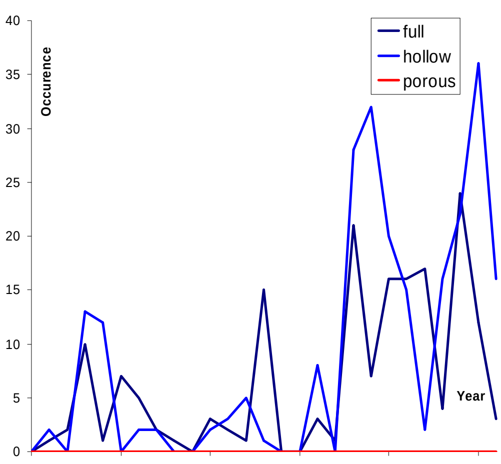


Fig12. Porosity Variation over Time

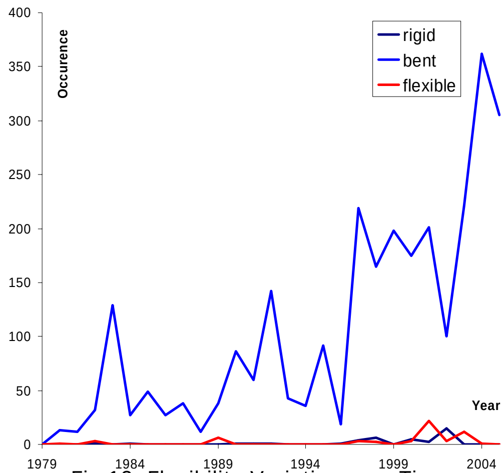


Fig 13. Flexibility Variation over Time

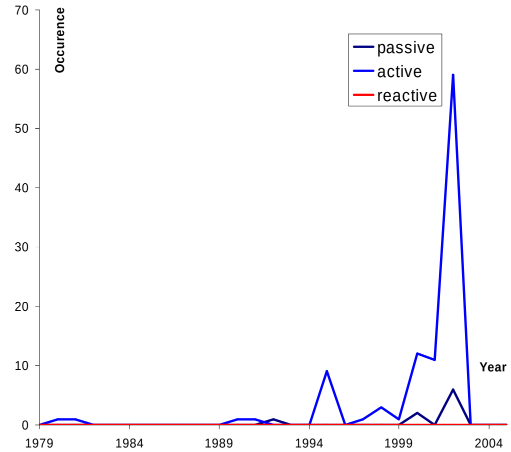
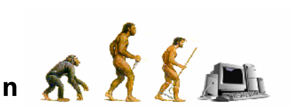


Fig14. Activity Variation over Time

In addition to Figure 2 it is important to evaluate how the property evolves overtime. Fig. 11 indicates that still a lot of work is done on smooth piston rings, while protruded will give less heat and friction. Fig 9 gives the impression that a lot of work is done on fluids, referring in this case to the oil used in the piston. Fig 10 shows that a there is recently more patent activity on linearity in piston rings, while curvature in piston rings could have advantages in heat and friction development.

Conclusion



People are good at judgment, understanding, reasoning, problem solving and creativity. Computers are good at memory, searching through large database, multi-location, and multi-tasking. The question is not to compare results but to combine forces to **Computer Aided Innovation**.

Even though the calculation of the software may take several hours, the report proves usefull and enlightening to the researcher. There is still a lot of noise in the software which is being fine tuned with semantic processing. The software provides a powerful tool for looking for white spaces, current and past activity on specific materials and properties, upcoming technologies and competitors.

Further work is directed to connect the distilled functions into a priority listing of suggested property variations. This will be reinforced with data where these functions have been achieved by varying the suggested properties, in totally different domains.

Simon Dewulf is Managing Director of CREAX; a company of creative engineers active in innovation consulting, patents studies, systematic innovation methodologies, product development, training and innovation culture coaching. With directed variation®, DIVA, CREAX brings a checklist for innovation potential that acts as a turbo for new value creation. By combining worldwide best practices in Business, Technology and Management, CREAX offers an integrated innovation method that acts as a toolbox, a philosophy and a culture for value creation. CREAX works for market leaders and innovation driven companies in all sectors including Goodyear, P&G, Shell, Masterfoods, Atlas Copco, Solvay and Bekaert. CREAX teams up Bernard Lahousse, Nele Dekeyser, Mathieu Mottrie, Johan Langenbick, Lieven De Couvreur, Nadine Rits, Lieselot Vandecappelle, Vincent Theeten, Katleen Pyck, Frederick Florizoone, Thomas Valcke, Frederick Vandendriessche, and Simon Dewulf.