Structural multi-objective optimization of material composition for present properties

IOSO Optimization software allows for concentrations of a number of alloying elements to be optimized so that a finite number of properties (maximum tensile strength, maximum operating temperature, maximum time-until-rupture, minimum weight, minimum cost, etc.) of the alloy are simultaneously extremized, while satisfying a number of equality and inequality constraints.

Concentrations of the following 17 elements were taken as independent variables:
C, S, P, Cr, Ni, Mn, Si, Cu, Mo, Pb, Co, Cb, W, Sn, Al, Zn, Ti.

In many applications it is highly desirable to use as light alloys as possible. Furthermore, certain alloying elements are considerably more expensive than other elements.

The following parameters were then used as optimization objectives:

- Stress (PSI – maximize)
- Operating temperature (T – maximize)
- Time to "survive" until rupture (Hours – maximize)
- Cost of the raw ingredients
- Density of the resulting metal alloy

CONCLUSIONS

These design methods are applicable to design of any type of alloys and could account for additional desired features of new alloys like corrosion resistance, microstructure features, thermal and mechanical treatment, manufacturing cost, etc.

1.Dulikravich,G.S., Egorov,I.N., Sikka,V.K. and Muralidharan,G. "Semi-Stochastic Multi-Objective Optimization of Hemical Composition of High Temperature Austenitic Steels for Desired Mechanical Properties" (.pdf, 571Kb), Symposium on Materials Processing Under the Influence of Electrical and Magnetic Fields, 2003 TMS Annual Meeting, San Diego, CA, March 2-6, 2003

2.G.S. Dulikravich and I.N. Egorov-Yegorov, “Robust Optimization of Concentrations of Alloying Elements in Steel for Maximum Temperature, Strength, Time-To-Rupture and Minimum Cost and Weight” (Paper presented at ECCOMAS – Computational Methods for Coupled Problems in Science and Engineering; eds: Papadrakakis, Onate, E. and Schrefler, B., Fira, Santorini Island, Greece, May 25-28, 2005).

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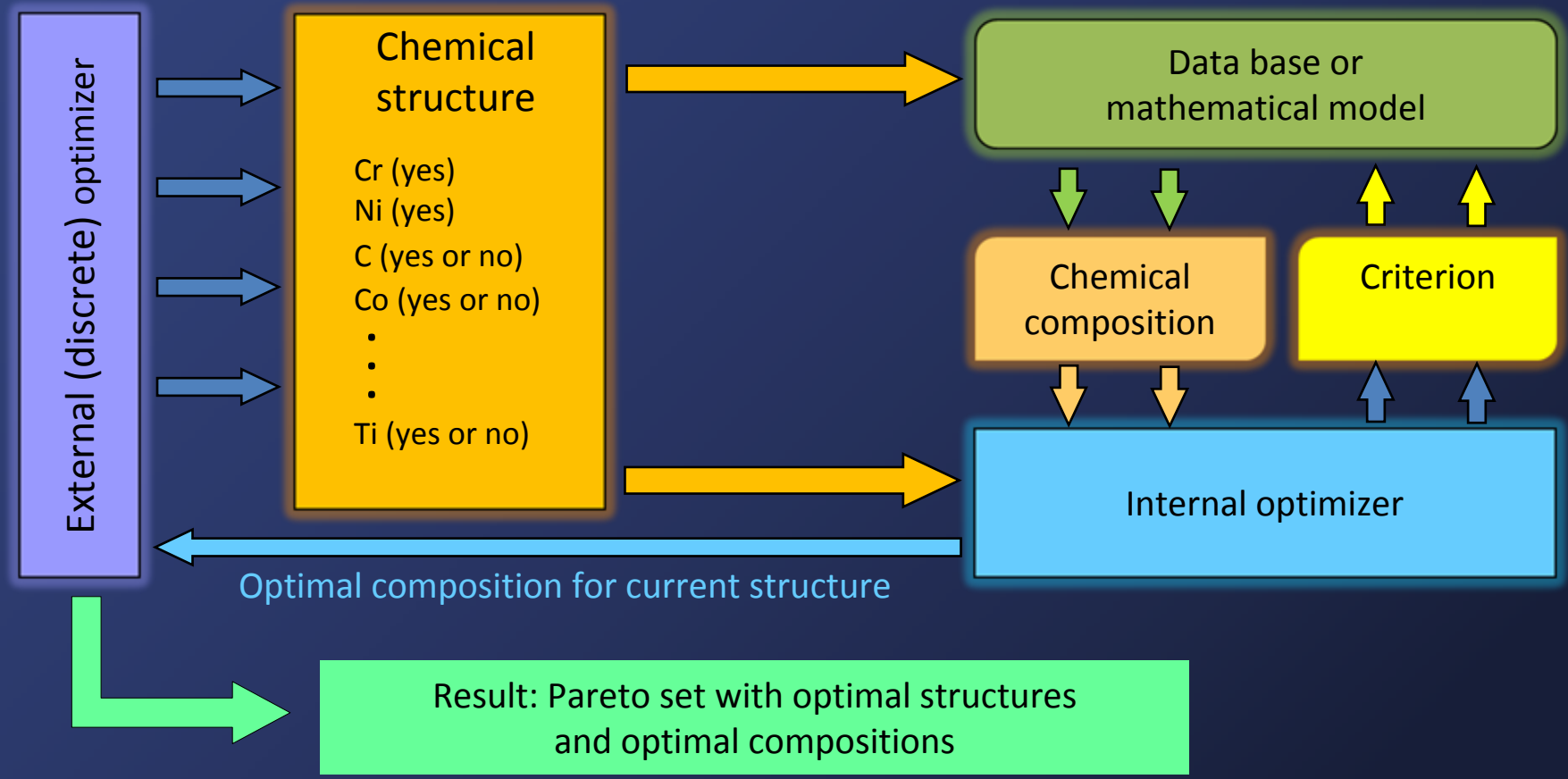
This work was done in the interests of and in conjunction with Florida International University and the University of Texas at Arlington.
The main objective of this work was to optimize the chemical structures of the alloys by varying the composition of their components.



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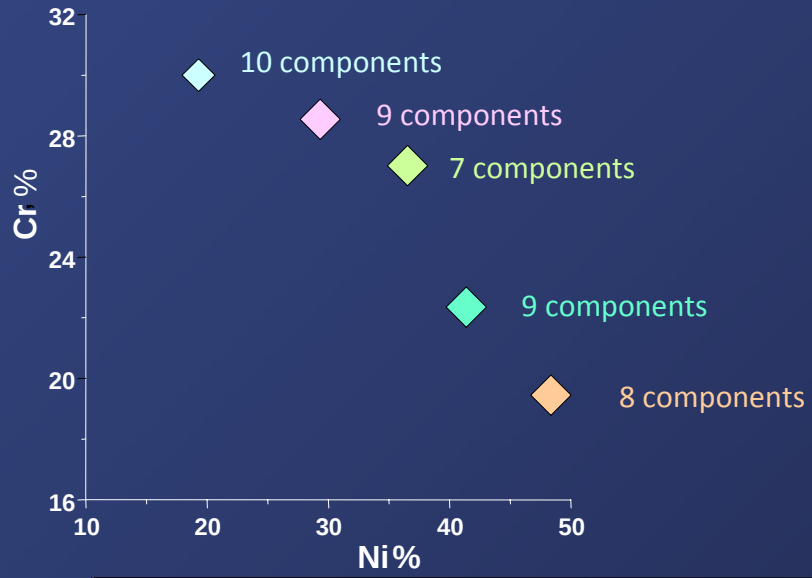

Preset properties:
stress=4000
temp.=1800
time=6000

Criteria:
Cr and Ni concentration.

The optimization of the composition of the alloys was aimed at minimizing the cost of the alloys while some kinds of constraints of the task were present. Alloys had to keep their properties under 6000 hours of stresses of 4000 psi with a temperature of 1800 F.

	C	S	P	Mn	Si	Cu	Mo	Pb	Co	Cb	W	Sn	Al	Zn	Ti
10	0.529	none	0.02	1.21	none	none	0.065	0.005	0.003	1.344	0.199	none	0.067	0.001	0.014
9	0.329	none	0.014	0.894	none	none	0.061	0.004	none	1.026	0.188	none	0.074	0.004	0.048
7	0.527	none	none	1.21	none	0.018	0.021	none	none	none	0.281	none	0.074	0.001	0.032
9	0.506	none	none	0.879	none	none	0.053	0.005	0.043	0.839	0.37	none	0.034	0.009	0.001
8	0.457	none	none	0.977	none	none	0.013	0.003	none	1.367	0.476	none	0.073	0.003	0.059

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As a result of the joint use of the experimental research and the IOSO optimization there were obtained Paretto set dependencies between properties and costs, for different chemical components, alloys and their compositions.