Optimization Case Study – Manufacturing Engineering

This example is taken from Engineering Optimization, Methods and Applications by G.V. Reklaitis, A Ravindran, and K. M. Ragsdell, published in 1983 by John Wiley & Sons.

This machining problem involves a single cutting tool turning a diameter in one pass. The decision variables are the cutting speed v and the feed per revolution f. Increasing the speed and feed reduces the actual machining time, and hence the machining cost, but it has an adverse effect on the life of the cutting tool and results in a higher tooling cost. In addition, the optimal values of v and f will depend on labor and overhead costs. The goal is to minimize the total cost per component.

Here is a summary of the variables included in the math model, with the solution values.

St	Input	Name	Output	Unit	Comment
					Machining Case Study
	0.15	x		$/min	Labor + overhead
	0.5	y		$	Tool cost per cutting edge
	2	TL		min	Nonproductive time
	1	Td		min	Tool changing time
	10	dist		in	Distance traveled by the tool in a turning pass
	153.4611	v		ft/min	Cutting speed
	0.035	f		in/rev	Feed
	2.5	D		in	Mean workpiece diameter
	0.25	dc		in	Depth of cut
	1583	Ftmax		lbf	Maximum tangential cutting force
	15	Pmax		hp	Maximum horsepower at the spindle
		Tc	1.2203	min	Machining time, including approach time
		T	10.1111	min	Tool life
		fmax	0.035	in/rev	Maximum feed
		Ft	7.2357	lbf	Tangential cutting force
		HP	0.0336	hp	Horsepower consumed in cutting
		c	0.5615	$	Cost per component
	113420	A			Constant
	0.3	n			Constant
	0.45	n1			Constant
	344.7	ct			Constant
	0.78	alpha			Constant
	380000	beta			Constant
	0.9	gamma			Constant
	2	delta			Constant

Here are the equations.

$$lam = \frac{12}{\pi \cdot D}$$

$$Tc = \frac{dist}{lam \cdot v \cdot f}$$

$$c = x \cdot TL + \frac{x \cdot dist}{lam \cdot v \cdot f} + \left[\frac{x \cdot Td \cdot dist}{lam \cdot A} + \frac{y \cdot dist}{lam \cdot A} \right] \cdot v^{\left[\frac{1}{n} - 1\right]} \cdot f^{\left[\frac{1}{n1} - 1\right]}$$

$$T = \frac{A}{v^{\left[\frac{1}{n}\right]} \cdot f^{\left[\frac{1}{n1}\right]}}$$

$$Ft = ct \cdot f^{alpha} \cdot dc^{gamma}$$

$$fmax = .001 \cdot \left[\frac{Ftmax}{ct \cdot dc^{gamma}} \right]^{\left[\frac{1}{alpha}\right]}$$

$$HP = \frac{Ft \cdot v}{33000}$$

$$Z = v \cdot f^{alpha}$$

$$Zmax = \frac{Pmax \cdot 33000}{ct \cdot dc^{gamma}}$$

$$Y = v^{delta} \cdot f$$

$$Ymin = beta$$

The TK Solver Optimizer is concisely configured as follows.