컴퓨터를 이용한 원가절감 및 품질향상

Optimization for Production Cost-Down and Quality Improvement by Computer

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1. 서 론

모든 제지관련 기술자들의 관심사항은 생산성 향상, 원가절감과 품질향상과 관련되어 있다. 설비투자를 통한 생산성 향상과 원재료, 부재료의 효율적 처리와 혼합을 통해 원가절감과 품질향상을 위해 많은 노력을 하고 있다. 이러한 노력들을 보다 효율적으로 수행하기 위해서는 크게 볼 때 두가지의 접근 방법이 있다. 즉 최근에 개발된 시뮬레이션 기법과 수치해석적 기법이 필요하다고 생각한다.

2. 시뮬레이션과 수치해석적 기법

생산성 향상, 원가절감, 품질향상을 위한 접근전략은 서로 복합적으로 관련되어 있지만 편의상 두가지로 나누어 볼 수 있다.

* 설비의 디자인과 운전조건을 향상시키기 위한 **<u>시뮬레이션 기법</u>**과
* 원가절감과 품질향상을 위한 실험수행과 결과분석 또는 현장 데이터의 분석을 위해 **<u>수치해석적 기법</u>**이 필요하다.

시뮬레이션의 일반적인 사항을 먼저 개괄적으로 알아보고, 수치해석적 기법에 대해 좀더 자세히 알아보자.

2. 1 시뮬레이션

시뮬레이션을 통해 효과를 볼 수 있는 제지 관련분야는 매우 광범위하지만 세분화 하여 나열해 보면 다음과 같다.

- 프로세스 디자인
- 작업자 훈련
- DCS 점검 및 시운전
- 공정최적화
- 데이터 일치화(data reconciliation)
- 수익성(profitability) 분석

시뮬레이션을 위해서 컴퓨터 모델이 있다면 비교적 적은 비용으로 깊이 있는 연구를 수행할 수 있다. 예를 들어 개별적인 입력 파라메타의 변화에 의한 영향을 알아보고, 디자인 파라메타와 설비의 운전조건을 분석해 볼 수 있고, 공정에 관련되어 있는 근본적인 이해를 할 수 있게 된다. 시뮬레이션은 어떻게 보면 실제 실험에 의한 결과보다 더 자세한 데이터를 제공해 준다. 시뮬레이션을 통해 기존 개념의 최적화(optimization)와 새로운 개념의 개발, 기술적 한계의 이해와 극복을 추구하고 있다.

현장 작업자들은 시뮬레이션을 통해 여러 가지 혜택을 받을 수 있는데, 예를 들면 (1) 품질 최적화, (2) 위험의 최소화, (3) 시운전의 조기 완성 및 정상운전의 조기 실현이 그것이다. 시뮬레이션을 통해 설치한 설비의 개념(특성)을 각

공장의 현실조건에 맞추어 생산제품의 품질을 향상시킬 수 있게 된다. 시뮬레이션은 물리적 법칙에 근거하여 수행되는데, 제지산업에서는 주로 열역학, 유체역학과 재료역학(materials mechanics)에 관련된 법칙들이다.

유체역학

어프로치 시스템, 헤드박스, 초조부, 프레스, 도공기술 등에 유체역학적 시뮬레이션이 필요하다.

재료역학

거의 모든 공정의 시뮬레이션에 재료역학적 법칙들이 사용되는데, 탄성, 점성, 소성적 거동을 좌우하며, 지료의 점도와 투과성(permeability)에 재료역학적 시뮬레이션이 필요하다.

2. 1. 1 시뮬레이션 단계

시뮬레이션을 수행하는 단계는 다음과 같이 나눌 수 있는데, 필요한 경에 따라 서로 순환할 필요도 있다.

(1) 물리법칙
(2) 수학적 모델
(3) 시뮬레이션 알고리듬
(4) 컴퓨터 프로그램
(5) 파라메타 동정(parameter identification)
(6) 모델검증
(7) 적용

수학적 시뮬레이션 모델은 관련된 식들을 통합하여 만들게 되는데, 해석학적으

로(analytical) 풀 수 있는 경우는 매우 드물고, 대부분의 경우 수치해석적 기법이 필요하다. 시뮬레이션 알고리듬을 컴퓨터 프로그램으로 바꿔줘야 함은 물론, 시뮬레이션 하고자 하는 설비 또는 공정의 파라메타를 (예를 들어 실험실적 실험을 통하여) 결정해야 한다. 사용자에 의해 적용하기 이전에, 시뮬레이션 모델을 실제 실험결과와 비교하여 검증하고 필요하면 수정해야 한다. 시뮬레이션과 실제적인 실험을 병행해야 효율적인 업무추진이 가능해 진다.

초지공정에 관련하여 시뮬레이션은 각 공정에서 다양한 역할을 수행할 수 있다. (1) 헤드박스에서는 지료의 혼합, 제트의 기하학, 섬유의 배열(방향성), (2) 금망부에서는 와이어의 이동, 섬유와 충전제의 분포, (3) 압착부에서는 압착탈수, (4) 건조부에서는 열의 흐름, 지필의 이동, 습지의 수축, (5) 도공부에서는 도공액의 흐름, 접촉 진동(contact vibrations), (6) 권취부에서는 롤구조(roll structure), 릴교체에 매우 유용하게 적용할 수 있다.

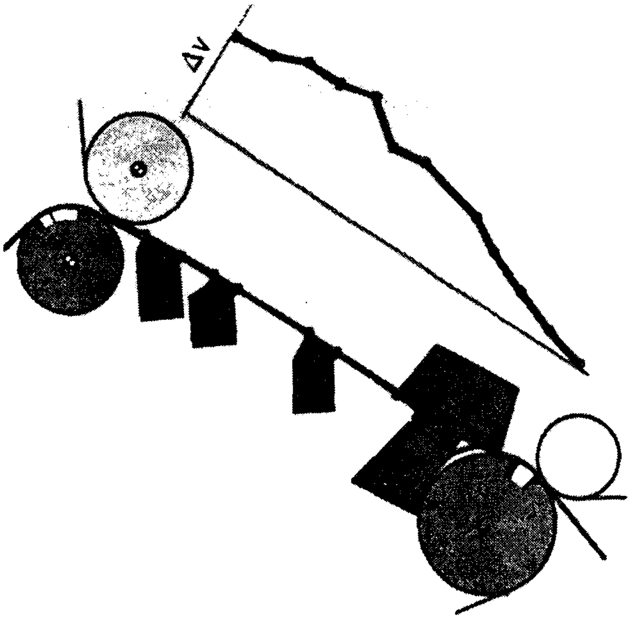
시뮬레이션의 적용 예

초조공정의 상대속도(relative velocity) 축 바(bars)와 와이어 사이에서 측정한 마찰계수를 이용하여 흡인설비(suction elements)의 진공을 마찰력으로 환산해 주는 시뮬레이션 모델을 만들 수 있다. 이러한 모델을 통하여 초조공정과 관련된 현상의 깊이 있는 이해를 가능케 해주었다. (그림 1)

Tandem shoe press의 첫 번째 프레스에서 탈수되는 종이두께 방향의 물의 유속을 나타내는 그림으로, 초기에는 탈수가 종이표면에 국한되어 있고, 점차 닙을 통과해 가면서 점차 종이두께 내부로 진행한다. 닙을 빠져나오면 두께방향으로 탄성적으로 약간 두꺼워지게 된다. (그림 2)

프레스 닙을 빠져나온 지필은 종이표면의 건조도(dry content)가 상당히 높다. 그러나 종이두께 중앙의 함수율은 상당히 높은 상태로 남아있다.(그림 3)

Reference : Process simulation - Virtual papermaking, Dr. Jorg Reuter, Dr. Florian Wegmann, Twogether 15, p. 51-53, Feb. 2003.


Δv

그림

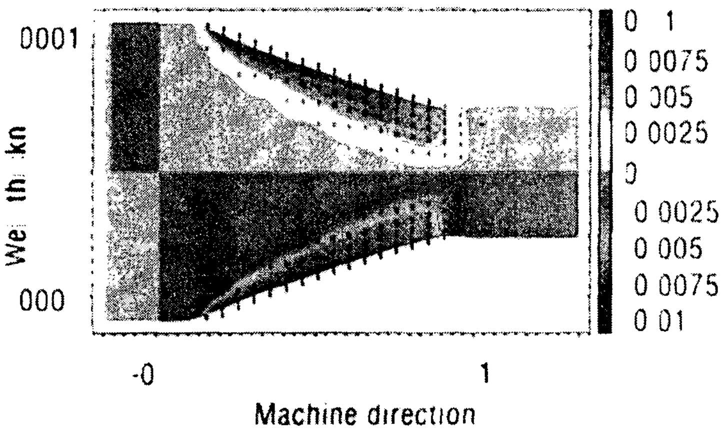

0001
000
-0
1
Machine direction
0 1
0 0075
0 005
0 0025
0
0 0025
0 005
0 0075
0 01

그림 2

시운전 기간단축, 조기 정상조업을 통한 영업이익의 극대화를 꾀할 수 있었는데, 브라질의 년산 70만톤 펄프공장이 digester, pressure diffusers, oxygen-delignification on screening, bleaching, chlorine dioxide plant, pulp drying, evaporation, recausticizing and lime reburning 측면에서 시뮬레이션이 되어 있어서 프로젝트 팀이 시운전을 조기에 완료하고 정상조업을 하므로써 계획보다 훨씬 빨리 2002년 5월 23일 조업을 개시하게 되었다. (그림 4. 계획 시운전 기간을 1년에서 6개월로 단축하였을 때의 경제적 효과.)

Reference : Using dynamic process simulation for business and risk management, Bill Thomas, AMEC, Solutions! for people, Processes and Paper, p. 36-37, May 2003.

2. 2 수치해석적 기법

큰 설비투자 없이 비교적 쉽게 접근할 수 있는 컴퓨터를 이용한 수치해석적 기법에 관하여 자세히 알아보고자 한다. 기술자들이 노력하고 있는 원가절감은 최소화(minimization)의 문제이고 품질향상은 최대화(maximization)의 문제라고 간략하게 생각할 수 있다.

2. 2. 1 수치해석적 기법의 종류

이분법(Bisection method)

알고 있는 이론식 또는 실험식을 이용하여 근을 구하는 방법의 하나로 이용할 수 있다. 근을 구한다는 것은 품질의 목표치를 얻기 위한 조건들을 구하는 것이 된다.

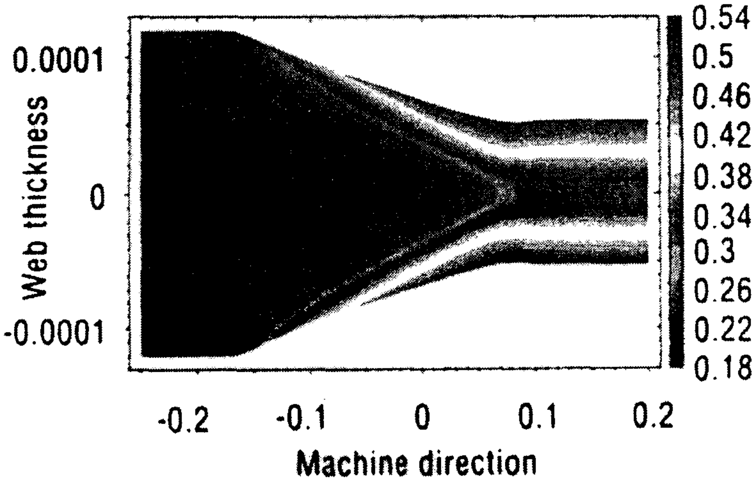


그림 3

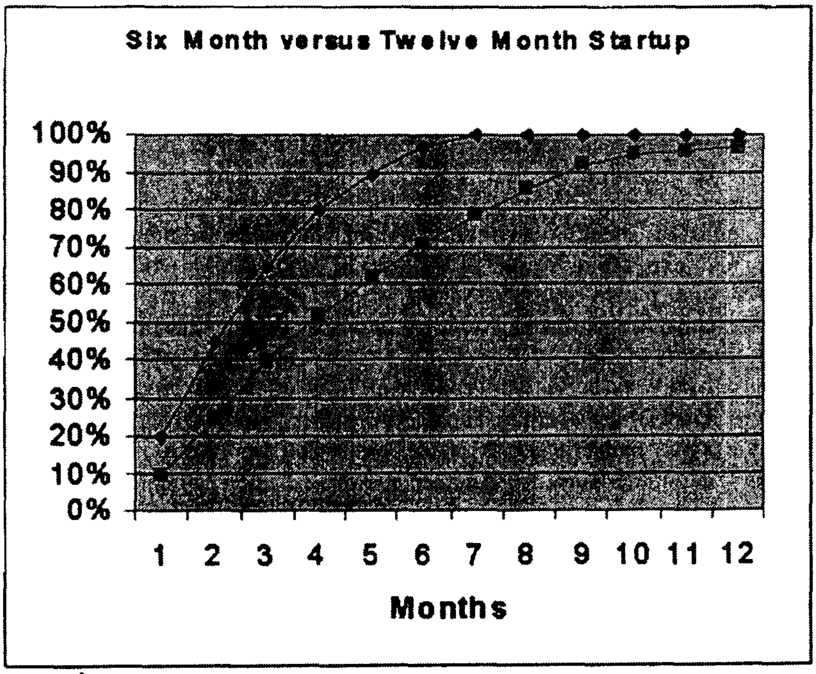


Figure 4: The economic incentives are significant moving from a six-month startup versus 12 months.

가위치법(False-Position method)

이분법에 비하여 좀더 효율적으로 근을 구할 수 있는 방법이다. 이분법은 상한치와 하한치의 중간에 근이 있는지를 확인하면서 가상치를 다시 설정하는 단계를 밟지만, 가위치법은 가상치의 위치를 함수 값을 직선적으로 가상하여 효율적으로 근에 접근하는 방법이다.

선형 프로그래밍(Linear Programming)

목적함수와 구속조건이 선형인 경우의 최적화를 위한 프로그래밍이다. 선형 프로그래밍은 수천 개의 변수와 구속조건을 갖고 있는 대형문제도 매우 효율적으로 계산할 수 있다.

비선형 프로그래밍(Non-Linear Programming)

비선형 최적화 문제는 여러 가지가 있는데, 크게 나누어 직접방법과 간접방법이 있다. 대표적인 간접방법은 벌칙함수(penalty functions)를 사용하는 것이다. 이 방법은 해가 구속조건에 접근하면서 목적함수가 덜 최적화되도록 하는 부가적인 식을 사용하는 것이다. 직접방법 중에서 대표적인 것은 일반적인 확산구배 탐색법(generalized reduced gradient (GRG) search) 혹은 GRG법이 있다. 엑셀에서는 GRG법을 이용하여 해구하기(solver)를 수행한다.

엑셀 프로그램을 이용한 최적화의 예

참고 1

(Reference : Numerical Methods for Engineers - With Software and Programming Applications, 4th ed., S.C. Chapra, R. P. Canale, McGraw Hill, 2002, p.387-393)

15.3 OPTIMIZATION WITH PACKAGES

Software libraries and packages have great capabilities for optimization. In this section, we will give you an introduction to some of the more useful ones.

15.3.1 Excel for Linear Programming

There are a variety of software packages expressly designed to implement linear programming. However, because of its broad availability, we will focus on the Excel spreadsheet. This involves using the Solver option previously employed in Chap. 7 for root location.

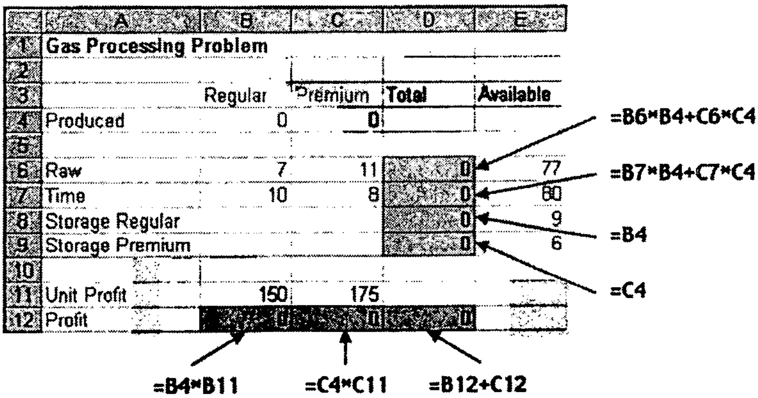
The manner in which Solver is used for linear programming is similar to our previous applications in that the data is entered into spreadsheet cells. The basic strategy is to arrive at a single cell that is to be optimized as a function of variations of other cells on the spreadsheet. The following example illustrates how this can be done for the gas-processing problem.

EXAMPLE 15.3 Using Excel's Solver for a Linear Programming Problem

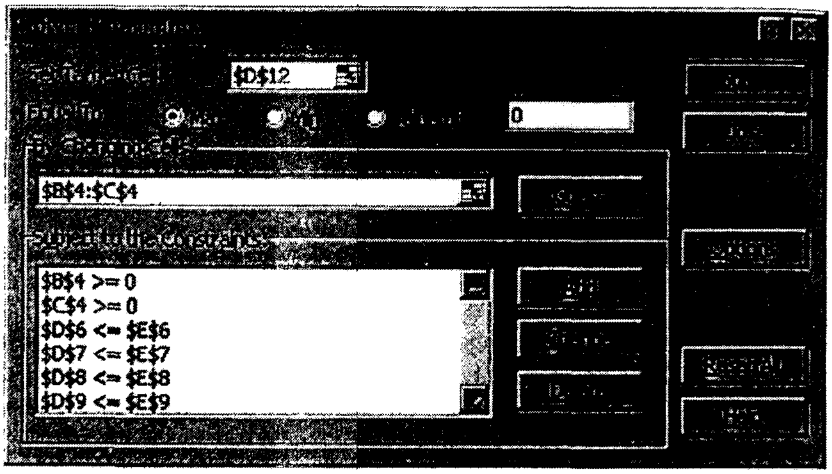
Problem Statement. Use Excel to solve the gas-processing problem we have been examining in this chapter.

Solution. An Excel worksheet set up to calculate the pertinent values in the gas-processing problem is shown in Fig. 15.4. The unshaded cells are those containing numeric and labeling data. The shaded cells involve quantities that are calculated based on other cells. Recognize that the cell to be maximized is D12, which contains the total profit. The cells to be varied are B4:C4, which hold the amounts of regular and premium gas produced.

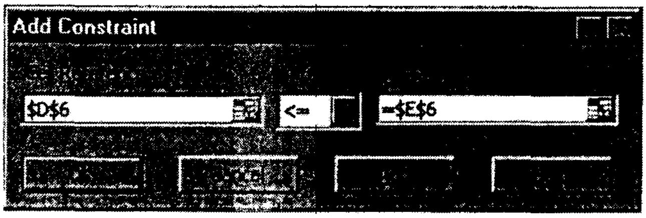
FIGURE 15.4
Excel spreadsheet set up to use the Solver for linear programming.



Once the spreadsheet is created, **Solver** is chosen from the Tools menu. At this point a dialogue box will be displayed, querying you for pertinent information. The pertinent cells of the Solver dialogue box are filled out as



The constraints must be added one by one by selecting the "Add" button. This will open up a dialogue box that looks like



As shown, the constraint that the total raw gas (cell D6) must be less than or equal to the available supply (E6) can be added as shown. After adding each constraint, the "Add" button can be selected. When all four constraints have been entered, the OK button is selected to return to the Solver dialogue box.

Now, before execution, the Solver options button should be selected and the box labeled "Assume linear model" should be checked off. This will make Excel employ a version of the simplex algorithm (rather than the more general nonlinear solver it usually uses) that will speed up your application.

After selecting this option, return to the Solver menu. When the OK button is selected, a dialogue box will open with a report on the success of the operation. For the present case, the Solver obtains the correct solution (Fig. 15.5)

	A	B	C	D	E
1	Gas Processing Problem				
2					
3		Regular	Premium	Total	Available
4	Produced	4.888889	3.888889		
5					
6	Raw	7	11	77	77
7	Time	10	8	80	80
8	Storage Regular			4.888889	9
9	Storage Premium			3.888889	6
10					
11	Unit Profit	150	175		
12	Profit	733.3333	680.5556	1413.889	

FIGURE 15.5
Excel spreadsheet showing solution to linear programming problem.

Beyond obtaining the solution, the Solver also provides some useful summary reports. We will explore these in the engineering application described in Sec. 16.2.

15.3.2 Excel for Nonlinear Optimization

The manner in which Solver is used for nonlinear optimization is similar to our previous applications in that the data is entered into spreadsheet cells. Once again, the basic strategy is to arrive at a single cell that is to be optimized as a function of variations of other cells on the spreadsheet. The following example illustrates how this can be done for the parachutist problem we set up in the introduction to this part of the book (recall Example PT4.1).

EXAMPLE 15.4 Using Excel's Solver for Nonlinear Constrained Optimization

Problem Statement. Recall from Example PT4.1 that we developed a nonlinear constrained optimization to minimize the cost for a parachute drop into a refugee camp. Parameters for this problem are

Parameter	Symbol	Value	Unit
			kg
			m/s^2
			\$
			\$/m
			\$/m^2
			m/s
			kg/(s·m^2)
			m

Substituting these values into Eqs. (PT4.11) through (PT4.19) gives

Minimize $C = n(200 + 56\ell + 0.1A^2)$

subject to

$v \leq 20$

$n \geq 1$

where n is an integer and all other variables are real. In addition, the following quantities are defined as

$$A = 2\pi r^2$$

$$\ell = \sqrt{2}r$$

$$c = 3A$$

$$m = \frac{M_t}{n} \tag{15.6}$$

$$t = \text{root}\left[500 - \frac{9.8m}{c}t + \frac{9.8m^2}{c^2}\left(1 - e^{-(c/m)t}\right)\right] \tag{15.7}$$

$$v = \frac{9.8m}{c}\left(1 - e^{-(c/m)t}\right)$$

Use Excel to solve this problem for the design variables r and n that minimize cost C.

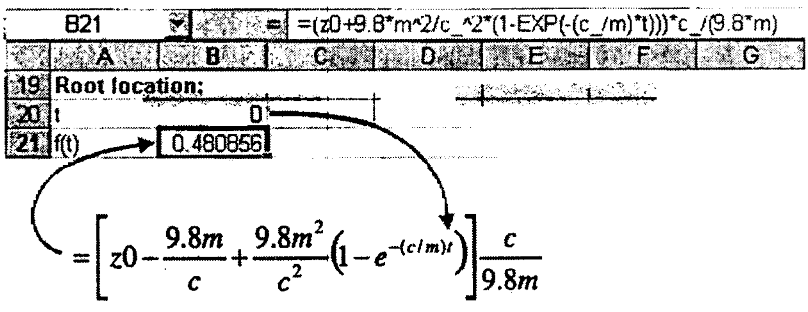
Solution. Before implementation of this problem on Excel, we must first deal with the problem of determining the root in the above formulation [Eq. (15.7)]. One method might be to develop a macro to implement a root-location method such as bisection or the secant method. (Note that we will illustrate how this is done in the next chapter in Sec. 16.3.)

For the time being, an easier approach is possible by developing the following fixed-point iteration solution to Eq. (15.7),

$$t_{i+1} = \left[500 + \frac{9.8m^2}{c^2}\left(1 - e^{-(c/m)t_i}\right)\right]\frac{c}{9.8m} \tag{15.8}$$

Thus, t can be adjusted until Eq. (15.8) is satisfied. It can be shown that for the range of parameters used in the present problem, this formula always converges.

Now, how can this equation be solved on a spreadsheet? As shown below, two cells can be set up to hold a value for t and for the right-hand side of Eq. (15.8) [that is, $f(t)$].



You can type Eq. (15.8) into cell B21 so that it gets its time value from cell B20 and the other parameter values from cells elsewhere on the sheet (see below for how we set up the whole sheet). Then go to cell B20 and point its value to cell B21.

Once you enter these formulations, you will immediately get the error message: "Cannot resolve circular references" because B20 depends on B21 and vice versa. Now, go to the Tools/Options selections from the menu and select **calculation.** From the calculation dialogue box, check off "iteration" and hit "OK." Immediately the spreadsheet will iterate these cells and the result will come out as

	A	B
19	**Root location:**	
20	t	10.2551
21	f(t)	10.25595

Thus, the cells will converge on the root. If you want to make it more precise, just strike the F9 key to make it iterate some more (the default is 100 iterations, which you can change if you wish).

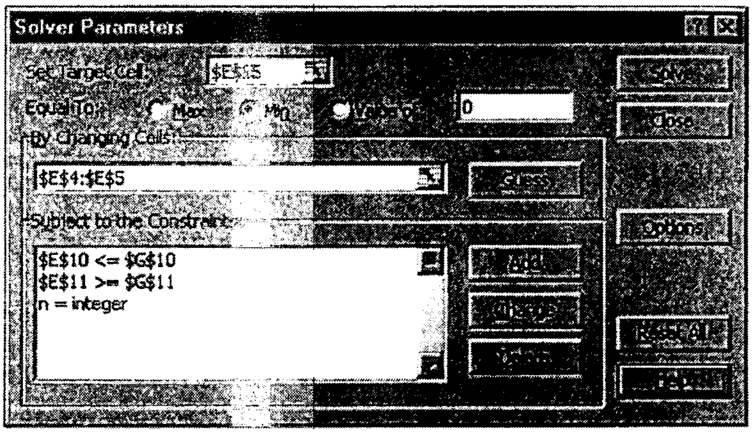
An Excel worksheet to calculate the pertinent values can then be set up as shown in Fig. 15.6. The unshaded cells are those containing numeric and labeling data. The shaded

FIGURE 15.6
Excel spreadsheet set up for the nonlinear parachute optimization problem

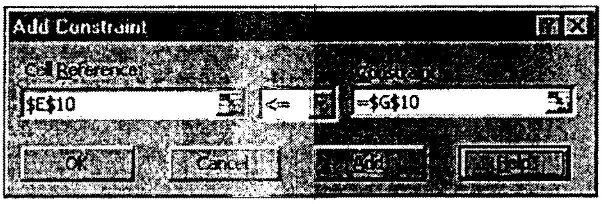
	A	B	C	D	E	F	G
1	**Parachute Optimization Problem**						
2							
3	**Parameters:**			**Design variables:**			
4	Mt	2000		r	1		
5	g	9.8		n	1		
6	cost1	200					
7	cost2	56		**Constraints:**			
8	cost3	0.1					
9	vc	20		**variable**		**type**	**limit**
10	kc	3		v	95.8786	<=	20
11	z0	500		n	1	>=	1
12							
13	**Calculated values:**			**Objective function:**			
14	A	6.283185					
15	l	1.414214		Cost	283.1438		
16	c	18.84956					
17	m	2000					
18							
19	**Root location:**						
20	t	10.26439					
21	f(t)	10.26439					

cells involve quantities that are calculated based on other cells. For example, the mass in B17 was computed with Eq. (15.6) based on the values for M_t (B4) and n (E5). Note also that some cells are redundant. For example, cell E11 points back to cell E5. The information is repeated in cell E11 so that the structure of the constraints is evident from the sheet. Finally, recognize that the cell to be minimized is E15, which contains the total cost. The cells to be varied are E4:E5, which hold the radius and the number of parachutes.

Once the spreadsheet is created, the selection Solver is chosen from the Tools menu. At this point a dialogue box will be displayed, querying you for pertinent information. The pertinent cells of the Solver dialogue box would be filled out as

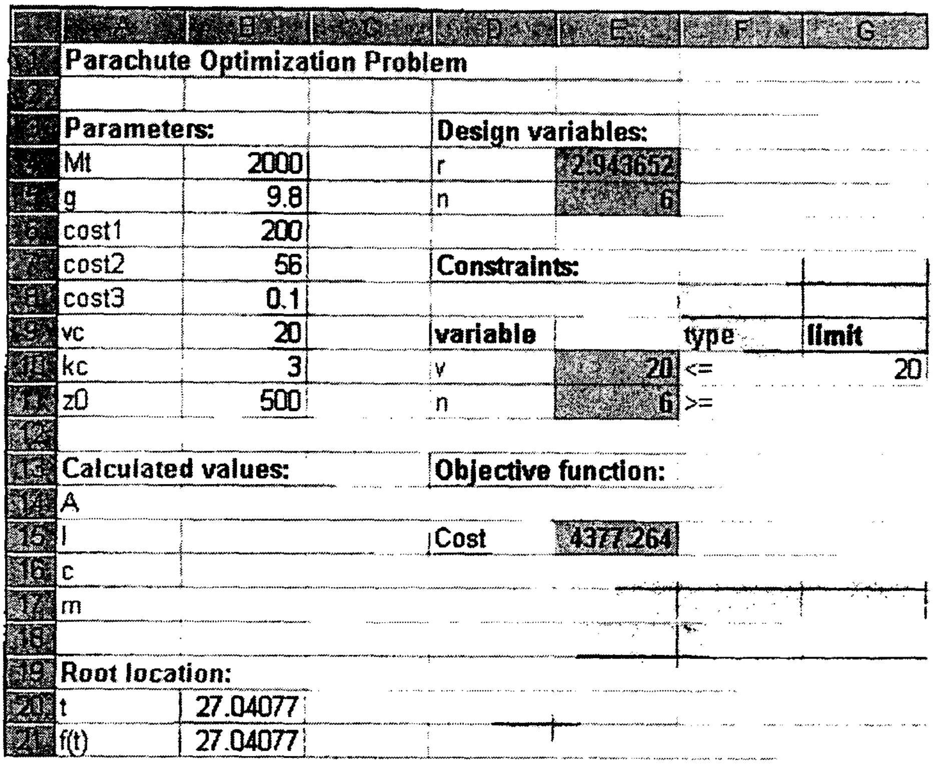


The constraints must be added one by one by selecting the "Add" button. This will open up a dialogue box that looks like



As shown, the constraint that the actual impact velocity (cell E10) must be less than or equal to the required velocity (G10) can be added as shown. After adding each constraint, the "Add" button can be selected. Note that the down arrow allows you to choose among several types of constraints (<=, >=, =, and integer). Thus, we can force the number of parachutes (E5) to be an integer.

When all three constraints have been entered, the "OK" button is selected to return to the Solver dialogue box. After selecting this option return to the Solver menu. When the "OK" button is selected, a dialogue box will open with a report on the success of the operation. For the present case, the Solver obtains the correct solution as in Fig. 15.7.



	A	B	C	D	E	F	G
1	Parachute Optimization Problem						
2							
3	Parameters:			Design variables:			
4	Mt	2000		r	2.943652		
5	g	9.8		n	6		
6	cost1	200					
7	cost2	56		Constraints:			
8	cost3	0.1					
9	vc	20		variable		type	limit
10	kc	3		v	20	<=	20
11	z0	500		n	6	>=	
12							
13	Calculated values:			Objective function:			
14	A						
15	I			Cost	4377.264		
16	c						
17	m						
18							
19	Root location:						
20	t	27.04077					
21	f(t)	27.04077					

FIGURE 15.7
Excel spreadsheet showing the solution for the nonlinear parachute optimization problem.

Thus, we determine that the minimum cost of $4377.26 will occur if we break the load up into six parcels with a chute radius of 2.944 m. Beyond obtaining the solution, the Solver also provides some useful summary reports. We will explore these in the engineering application described in Sec. 16.2.

제지공정에 관련된 최적화의 예

고해의 최적화

백상지 생산에 있어 요구되는 최종제품의 특성에 따라 원료섬유를 선택하곤 한다. 일반적으로 작업성을 위해 긴 섬유장과 높은 결합능력 때문에 침엽수를 사용하고, 섬유장이 짧고 그 분포가 매우 균일하므로 광학적 특성과 표면 평활성이 좋으므로 활엽수 섬유를 사용하게 된다. 따라서 원료섬유의 선택을 통해 최종제품 품질의 최적화를 달성하게 된다. 그러나 초지기 헤드박스 직전의 펄프의 품질은 펄프화 방법, 분리(fractionation) 및 고해에 따라 달라지게 된다.
백상지는 다양한 인쇄, 필기용도에 사용되는 종이이다. 일반적으로 백상지는 95-50%의 표백 활엽수 펄프를 사용하고 5-50%의 표백 침엽수 펄프를 사용한다.

참고 2

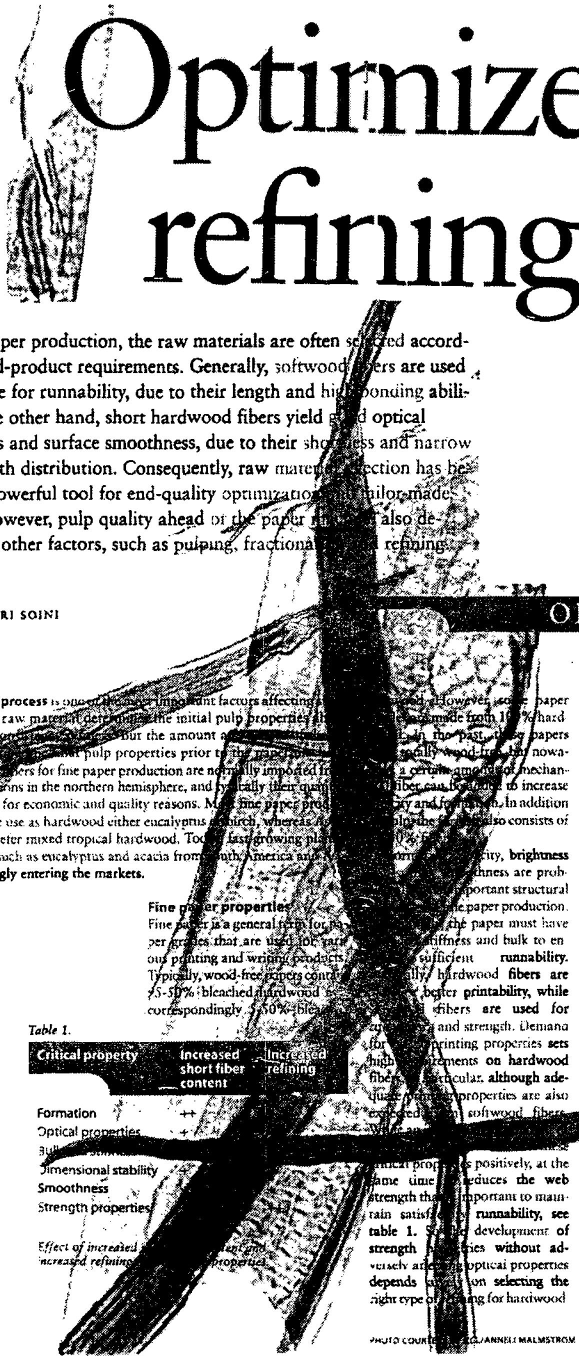
Reference : Optimized refining, Petteri Soini, Fiber & Paper, p. 24-25, Vol. 2, Issue 2, 2000.

디지털 인쇄를 위한 종이의 표면특성 최적화

최근에 많은 관심을 끌고 있는 디지털 인쇄를 위한 종이의 표면특성 최적화에 관한 연구를 목표로 삼고 접근해 보자. (*참고문헌 : 스웨덴 전략연구위원회에 2000년 3월에 보고된 S2P2 프로젝트 2000-2005 5개년계획에 표면특성에 관한 산학연구 제안서가 있었음*)

Optimized refining

In fine paper production, the raw materials are often se[illegible]ed according to end-product requirements. Generally, softwoo[illegible]ers are used to provide for runnability, due to their length and hi[illegible]bonding ability. On the other hand, short hardwood fibers yield [illegible]d optical properties and surface smoothness, due to their sho[illegible]ss and narrow fiber length distribution. Consequently, raw mate[illegible]ction has become a powerful tool for end-quality optimizatio[illegible]ilor-made pulps. However, pulp quality ahead of the paper [illegible] also depends on other factors, such as pulping, fractiona[illegible] refining.



BY PETTERI SOINI

OF SHORT FIB[illegible]

The refining process is one of the [illegible] important factors affecting [illegible] **quality.** The raw mater[illegible] determines the initial pulp properties [illegible] of the low-con[illegible] but the amount [illegible] fining dete[illegible] pulp properties prior to the papermak[illegible]

Softwo[illegible]ers for fine paper production are normally imported fr[illegible] various locations in the northern hemisphere, and typically their quan[illegible] is minimized for economic and quality reasons. M[illegible] fine paper prod[illegible] ers in Europe use as hardwood either eucalyptus [illegible] birch, whereas [illegible] producers prefer mixed tropical hardwood. To[illegible] fast-growing pla[illegible] tion species such as eucalyptus and acacia from [illegible]uth America and [illegible] **are increasingly entering the markets.**

[illegible] However, some paper [illegible] made from 100% hardwood [illegible]. In the past, [illegible] papers [illegible] usually wood-free, but nowa[illegible] a certain amount of mechan[illegible] fiber can be added to increase [illegible]ity and formation. In addition [illegible] pulp the [illegible] also consists of [illegible]0% [illegible] city, **brightness** [illegible]thness are prob[illegible] important structural [illegible] paper production.

Fine paper properties

Fine paper is a general term for pa[illegible] per grades that are used for vari[illegible] ous printing and writing products. Typically, wood-free papers conta[illegible] 75-50% bleached hardwood [illegible] correspondingly 5-50% bleac[illegible] [illegible] the paper must have [illegible] stiffness and bulk to en[illegible] sufficient **runnability.** [illegible]ally, hardwood **fibers are** [illegible] better **printability, while** [illegible] fibers **are used for** [illegible] and strength. Demand for [illegible] printing properties **sets** high [illegible]ements **on hardwood** fibers [illegible] particular, **although adequate** [illegible] properties are also expected [illegible] softwood fibers. [illegible] [illegible] properties positively, at the same time [illegible] reduces **the web** strength tha[illegible] important to maintain satisf[illegible] **runnability, see table 1.** [illegible] development of **strength** [illegible]ies **without ad**versely af[illegible] optical properties **depends** [illegible] on **selecting the** right type of [illegible]ing for hardwood

Table 1.

Critical property	Increased short fiber content	Increased refining
Formation	++	[illegible]
Optical properties	+	[illegible]
Bul[illegible]	[illegible]	[illegible]
Dimensional stability	[illegible]	[illegible]
Smoothness	[illegible]	[illegible]
Strength properties	[illegible]	[illegible]

Effect of increased [illegible]ent and increased refining [illegible] properties.

PHOTO COURT[illegible]/ANNELI MALMSTROM

Refining of short fiber

The morphological structures of different short fibers reveal most of those properties that can be further developed through low-consistency refining. The quality of hardwood pulps can be evaluated through fiber width and length, coarseness and hemi-cellulose content, figure 1.

Selection of the right raw material is becoming one of the most important factors in assuring high printing quality. Figure 2 presents the internal differences between short-fiber pulps.

Fiber dimensions of hardwoods illustration

Hardwood fibers are generally easy to refine. The energy consumption required to achieve practical freeness is relatively low and the desired fiber properties are exposed at [illegible] a low refining intensi[illegible] tropical hardwoods are an exception and typically require higher energy, coarser fillings and higher intensity. However, the higher energy requirement can be balanced by using modern low-energy conical refiners with a large selection of specialized refiner fillings.

Strength properties are emphasized in runnability and converting. High tensile strength and

Table 2.

	Birch	Eucalyptus	Acacia	MTH
Formation	–		0	
Opacity	–		0	
Smoothness	-(-)	-	0	
Strength	++	+	0	
Bulk/stiffness		0	0	

The relative potential of short fibers for key fine paper properties compared with the potential of acacia.

FOR FINE PAPER

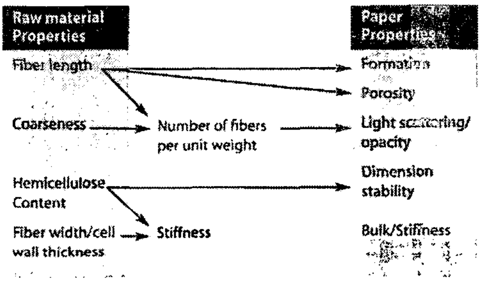


Figure 1.
Effect of raw material properties on the papermaking properties of short-fiber pulp.

	MTH	Eucalyptus	Acacia	Birch
Fiber length	0.9mm	0.7mm	0.7mm	0.9mm
Coarseness, µg/m	132	82	76	115

	MTH	Eucalyptus	Acacia	Birch
Fiber width	18µm	16µm	16µm	20µm
Lumen width	12µm	8µm	10µm	12µm
Cell wall	4µm	4µm	3µm	4µm
Cell wall/width	45%	50%	38%	40%
Fibers/g, million	5	13	18	8

Figure 2.
Fiber dimensions of hardwoods.

ply bond are also desirable properties from the short-fiber component, especially when the long-fiber fraction is reduced, but they must not affect printability too much. Northern birch has the best strength potential. European eucalyptus is quite close to birch, whereas the tensile strength of both acacia and mixed tropical hardwood is more difficult to develop. Consequently, it is essential to get the best out of these fibers.

Optical properties such as light scattering and opacity correlate with the number of fibers per weight unit. Short fibers with a higher fiber number, such as acacia, yield the best optical properties. Coarse and long fibers, such as birch and mixed tropical hardwood, give the lowest light scattering and opacity. Short fiber length also has a positive effect on formation and porosity.

As shown in table 2, short-fiber pulps, such as acacia and eucalyptus, do give the best optical properties, whereas coarser birch fibers yield the best strength properties.

Tailored tools for fiber furnishes

The most important properties in fine paper production are good printing, formation and optical properties, stiffness, surface smoothness and sufficient strength. Since many of the important properties of fine paper are gained by using short fiber material, and since the current trend is towards the greater use of hardwoods, the importance of strength properties is increasing. Refining plays the most important role in achieving this goal.

Low-consistency refining is a process stage that has a major impact on final paper properties. A refining system that generates strength, with minimal effect on drainage and optical properties offers an advantage.

Modern Valmet conical Conflo® refiners ensure the achievement of high strength properties combined with good printing properties.

For the papermaker, optimized refining is a valuable tool to treat the various fiber furnish components in the desired way, to ensure that they are best suited for the end-product quality. ■

valmet

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<관련학문분야>

1. 표면 및 콜로이드화학

종이, 잉크, 토너의 표면화학

2. 지류도공 기술 및 인쇄적성 관련분야

종이화학(Paper Chemistry)
종이표면 - 광학특성
종이표면 - 인쇄적성 및 인쇄품질
종이표면 - 표면특성 분석
종이 - 물의 상호작용
신 광학특성분석기술

3. 화상분석을 통한 종이표면특성분석

4. 기계적 특성

재료역학 - 재료물질의 기계적 특성을 3차원적으로 시뮬레이션하기 위해 이방성, 소성 크리프, 점탄성과 변형 및 파괴를 이해

파괴 및 피로역학 - 재료물질에 하중이 가해질 때 크랙이 있는 경우응력의 집중과 변형과정에 사용되는 에너지와 크랙이 진행되는 과정전반을 이해

고체역학 실험방법 - 기초역학의 실험방법에 관한 기본 이론과 실제

종이제품의 특성 - 종이와 종이류 제품의 특성분석을 하되 인쇄공정에 관련하여 다층구조재료로서의 종이의 특성에 관하여 이해

참고 3

참고 4

Linear Programming Frequently Asked Questions

Optimization Technology Center of
Northwestern University and Argonne National Laboratory

Posted at http://www-unix.mcs.anl.gov/otc/Guide/faq/linear-programming-faq.html
Changes posted to Usenet newsgroup sci.op-research

Date of this version: April 1, 2003

- Q1. "What is Linear Programming?"
- Q2. "Where is there good software to solve LP problems?"
  - "Free" codes
  - Commercial codes and modeling systems
  - Free demos of commercial codes
- Q3. "Oh, and we also want to solve it as an integer program."
- Q4. "I wrote an optimization code. Where are some test models?"
- Q5. "What is MPS format?"
- Q6. Topics briefly covered:
  - Q6.1: "What is a modeling language?"
  - Q6.2: "How do I diagnose an infeasible LP model?"
  - Q6.3: "I want to know the specific constraints that contradict each other."
  - Q6.4: "I just want to know whether or not a feasible solution *exists*."
  - Q6.5: "I have an LP, except it's got several objective functions."
  - Q6.6: "I have an LP that has large almost-independent matrix blocks that are linked by a few constraints. Can I take advantage of this?"
  - Q6.7: "I am looking for an algorithm to compute the convex hull of a finite number of points in n-dimensional space."
  - Q6.8: "Are there any parallel LP codes?"
  - Q6.9: "What software is there for Network models?"
  - Q6.10: "What software is there for the Traveling Salesman Problem (TSP)?"
  - Q6.11: "What software is there for cutting or packing problems?"
  - Q6.12: "What software is there for linear programming under uncertainty?"
  - Q6.13: "I need to do post-optimal analysis."
  - Q6.14: "Do LP codes require a starting vertex?"
  - Q6.15: "How can I combat cycling in the Simplex algorithm?"
- Q7. "What references are there in this field?"
  - General reference
  - Textbooks
  - Presentations of LP modeling systems
  - Books containing source code
  - Additional books
  - Periodicals
  - Articles of interest
- Q8. "What's available online in this field?"
  - Online sources of optimization services
  - Online sources of optimization software

Nonlinear Programming Frequently Asked Questions

Optimization Technology Center of
Northwestern University and Argonne National Laboratory

Posted at http://www-unix.mcs.anl.gov/otc/Guide/faq/nonlinear-programming-faq.html
Changes posted to Usenet newsgroup sci.op-research

Date of this version: April , 2003

- Q1. "What is Nonlinear Programming?"
- Q2. "What software is there for nonlinear optimization?"
- Q3. "I wrote an optimization code. Where are some test models?"
- Q4. "What references are there in this field?"
- Q5. "What's available online in this field?"
- Q6. "Who maintains this FAQ list?"

See also the following pages
pertaining to mathematical programming and optimization modeling:

- The related Linear Programming FAQ.
- Harvey Greenberg's Mathematical Programming Glossary.
- The Optimization Online repository of reports and papers.
- The e-Optimization.community website.

- The NEOS Guide to optimization models and software.
- The Decision Tree for Optimization Software by H.D. Mittelmann and P. Spellucci.
- Software for Optimization: A Buyer's Guide by Robert Fourer.

- The NEOS Server for access to optimization solvers through the internet
- Hans Mittelmann's Benchmarks for Optimization Software.
- The *Computational Optimization and Applications* Software Forum

. . . and don't forget the Web search engines! Services such as google, go/infoseek, lycos, excite, and altavista can be surprisingly helpful in finding pages on particular problem types or application areas.

Q1. "What is Nonlinear Programming?"

A: A Nonlinear Program (NLP) is a problem that can be put into the form

```
minimize   F(x)

subject to gi(x)  = 0    for i = , ..., m1      where m1 >= 0
```