Motorcycle Cooling Fin

Harley-Davidson

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made by Cool Guys

Contents

Introduction

V-twin cam

2005 Harley-Davidson Dyna Super Glide Low Rider FXDL

- Displacement 1450cm^3
- Bore 95.18 mm
- Stroke 101.52 mm
- Torque 115.0nm 3000rpm

D.V & O.F

Design Variables

t : thickness of the fin

L : length of the fin

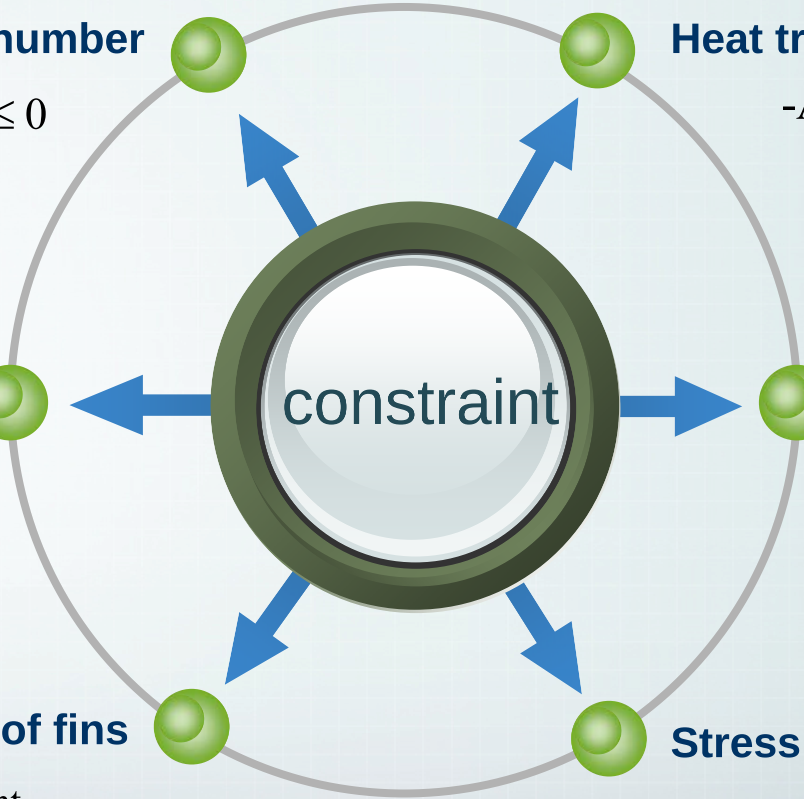
n : number of the fins

Objective Functions

Minimize Cost function $\min \ f = A_{fin} t \rho$

Maximize Heat transfer rate function $\mathrm{Max} \ f = A_{total} h(T - T_{\infty})$

Constraints



Positive number

$-t, -L, -n \le 0$

Heat transfer rate

$-Ah(T-T_{\infty})+Q_{total} \le 0$

Length limit

$L - L_a \le 0$

Fin's efficiency

$(L+\frac{1}{2}t)\sqrt{\frac{h}{kt}} - 0.17647 \le 0$

Intervals of fins

$3t-\frac{0.21-nt}{n} \le 0$

Stress at fin

$\sigma - \sigma_a \le 0$

Optimum solution

1. Former Design
2. Design Variable + 1
3. Objective function Change

Optimum solution-Design 1

Former Design – Minimize cost function , 2 Design variable (t , L)

Starting point=(2.4e-3,1.0e-2) Feasible region

Excel	fmincon	Pattern search	GA
GRG	**SQP**	**ALM**	**GA**
t=0.0021 m	**t=0.0021 m**	**t=0.0021 m**	**t=0.0022 m**
L=0.00834 m	**L=0.0083m**	**L=0.0083 m**	**L=0.0084 m**
f= 0.6548 kg	**f= 0.6548 kg**	**f= 0.6548 kg**	**f= 0.6940**

Optimum solution-Design 1

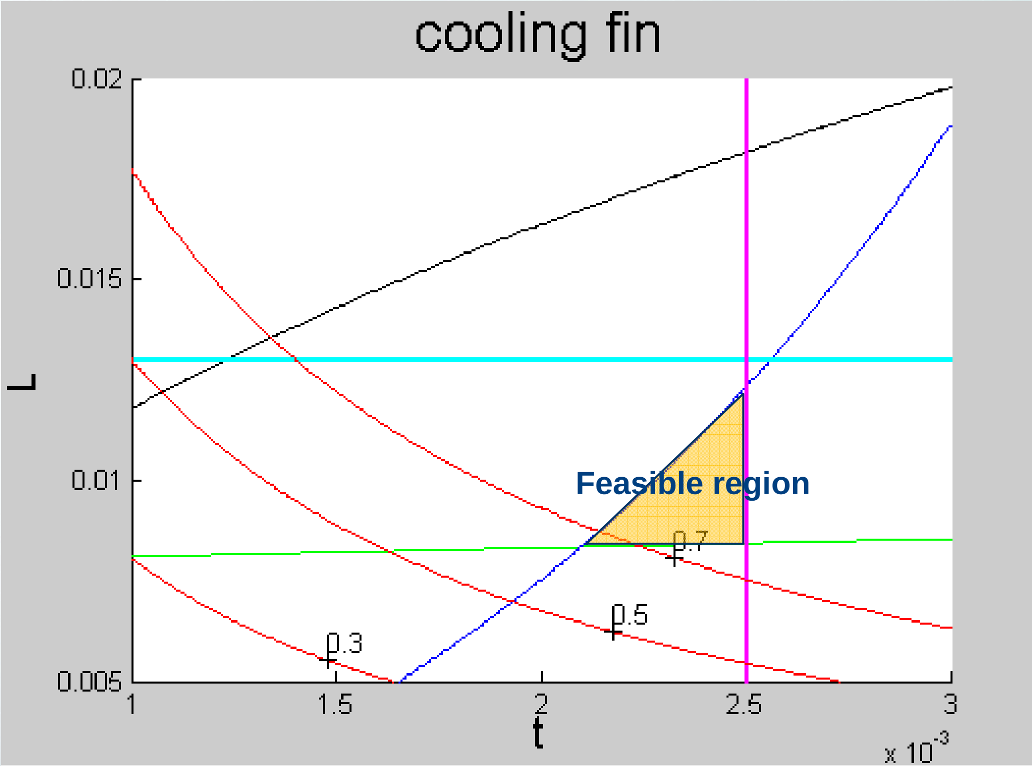
Former Design – Minimize cost function , 2 Design variable (t , L)

Starting point=(1.6e-3,1.5e-2) Infeasible region

Excel	fmincon	Pattern search	GA
GRG	**SQP**	**ALM**	**GA**
t=0.0021 m	**t=0.0021 m**	**t=0.0025 m**	**t=0.0022 m**
L=0.00834 m	**L=0.0083m**	**L=0.0084 m**	**L=0.0084 m**
f= 0.6548 kg	**f= 0.6548 kg**	**f= 0.7888 kg**	**f= 0.6940**

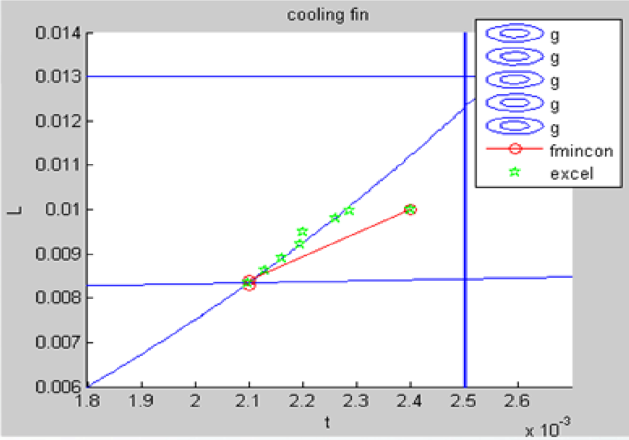
Optimum solution-Design 1

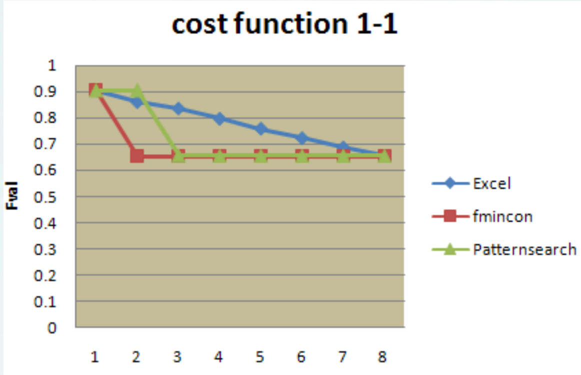
Graphical Method



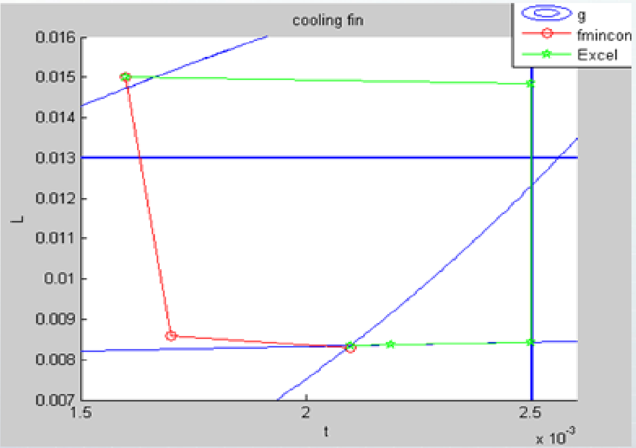
Optimum solution-Design 1

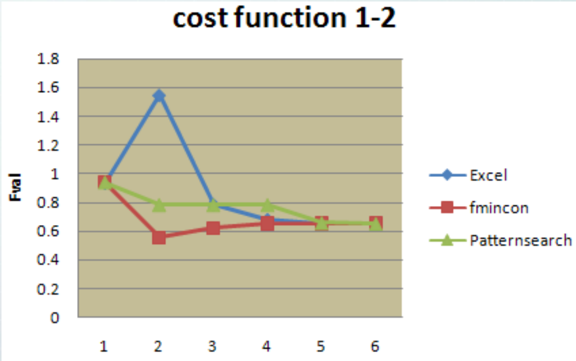
Plot iteration Point - feasible region





Plot iteration Point – Infeasible region





Optimum solution-Design 2

Variable + 1 – Minimize cost function , 3 Design variable (t , L , n)

Starting point=(2.4e-3,1.0e-2 ,20) Feasible region

Excel	fmincon	Pattern search	GA
GRG	SQP	ALM	GA
t=2.036 mm	t=1.7 mm	t=2.2 mm	t=1.9mm
L=7.808mm	L=5.6 mm	L=9.0 mm	L=6.6 mm
n= 21	n=30	n=18	n=25.355
f= 0.6298 kg	f= 0.5494 kg	f= 0.6677 kg	f= 0.5893 kg

Optimum solution-Design 2

t = 0.017 m L=0.0056 m n=30.08 f=0.5488kg → **n : Integer solution**

n=30

t= 0.0017m L= 0.0056m n=30.0000
f= 0.5494kg

n=31

none

n=29

t= 0.0018 L= 0.0058 n= 29.0000
f= 0.5566 kg

Integer solution

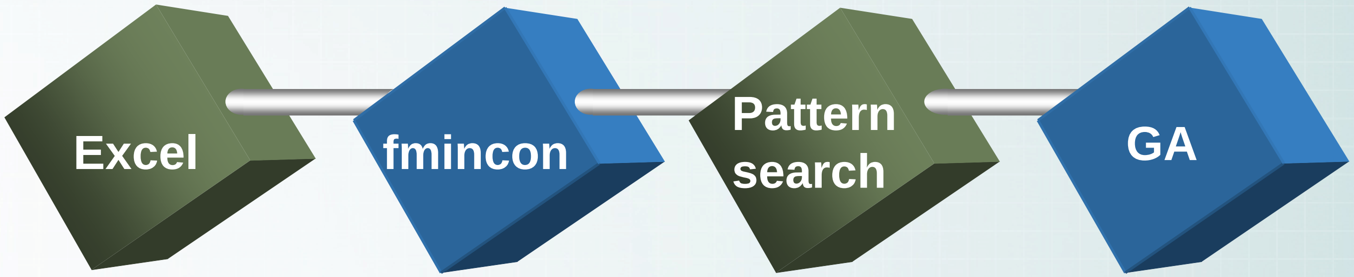
n=30

optimum

Optimum solution-Design 2

Variable + 1 – Minimize cost function , 3 Design variable (t , L , n)

Starting point=(1.6e-3,1.5e-2,10) Infeasible region

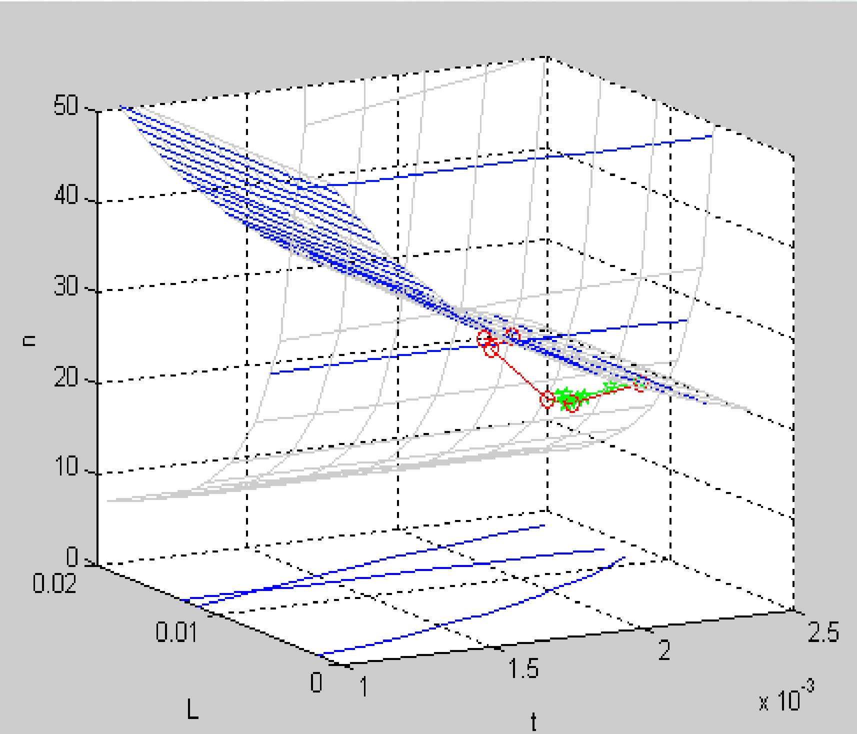


GRG	SQP	ALM	GA
t=2.48 mm	t=1.7 mm		t=1.9m
L=12.08 mm	L=5.6 mm		L=6.6 m
n= 13	n=30	none	n=25.355
f= 0.7536 kg	f= 0.5494 kg		f= 0.5893kg

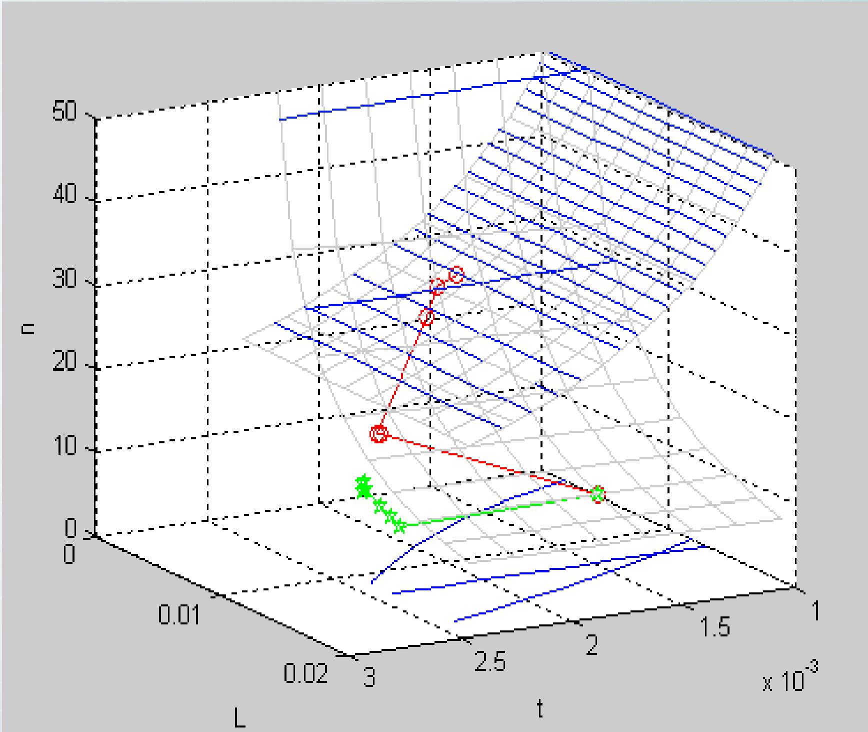
Optimum solution-Design 2

Design 2 – variables 3

Plot iteration Point - feasible region



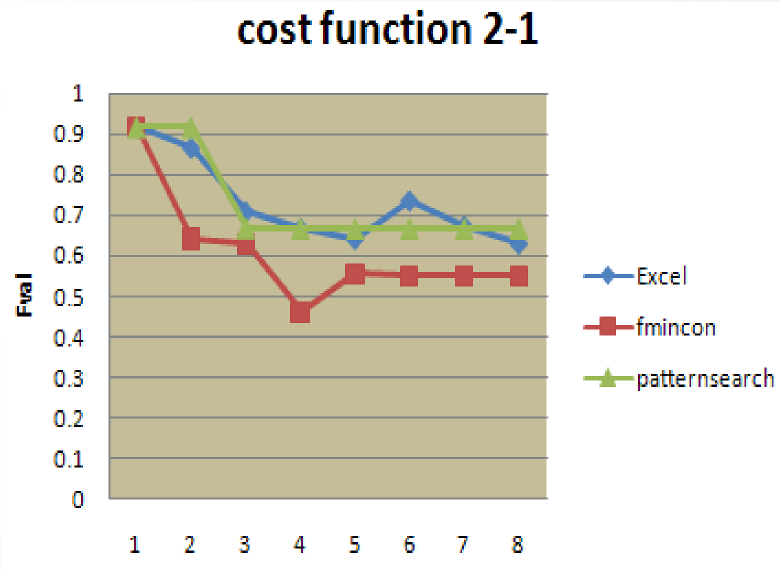
Plot iteration Point – Infeasible region



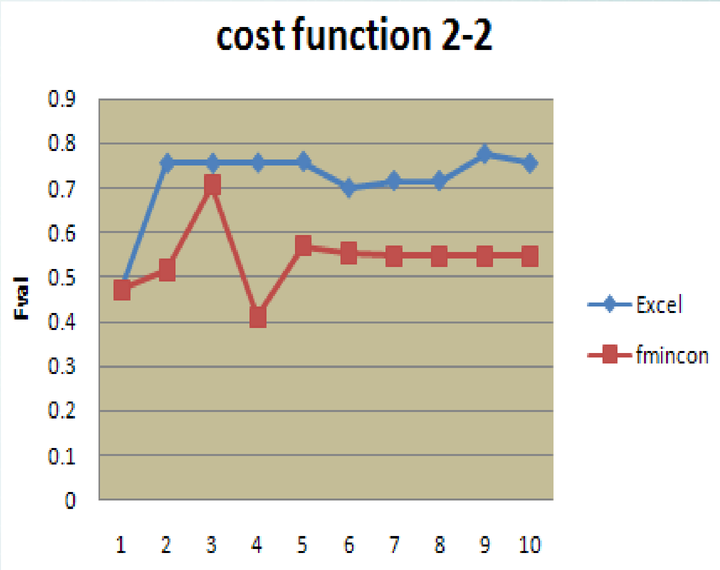
Optimum solution-Design 2

Design 2 – variables 3

Plot function value - feasible region



Plot function value – Infeasible region



Optimum solution-Design 3

Maximize Heat transfer rate , 3 Design variable (t , L , n)

Starting point=(2.4e-3,1.0e-2 ,20) Feasible region

Excel → fmincon → Pattern search → GA

Excel	fmincon	Pattern search	GA
GRG	SQP	ALM	GA
t=2.3 mm	t=2.3 mm	t=2.3 mm	t=2.2mm
L=9.7 mm	L=9.7mm	L=10.6 mm	L=9.6 mm
n= 23	n=23	n=22	n=23.3785
$\dot{Q}$ =-2413.4 W	$\dot{Q}$ =-2413.4 W	$\dot{Q}$ =-2386 W	$\dot{Q}$ =-2408 W

Optimum solution-Design 3

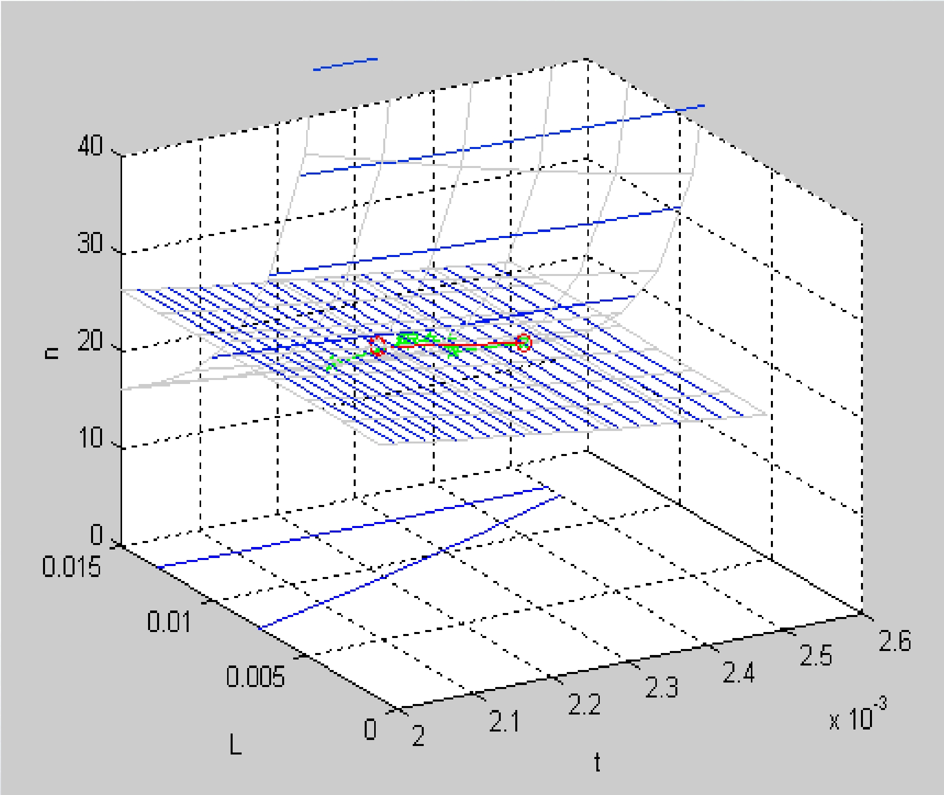
Maximize Heat transfer rate , 3 Design variable (t , L , n)

Starting point=(1.6e-3,1.5e-2,10) Infeasible region

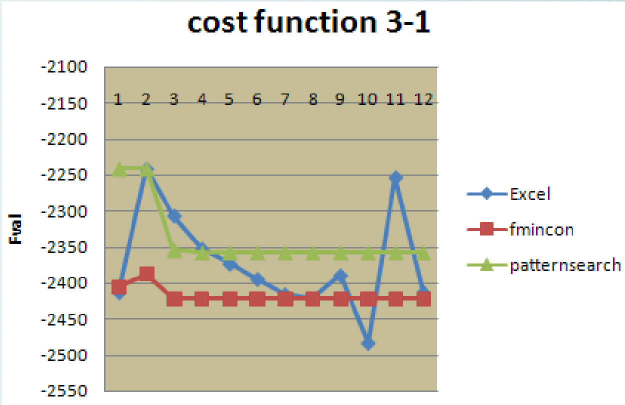
Excel	fmincon	Pattern search	GA
GRG	SQP	ALM	GA
t=2.6 mm			t=2.2mm
L=1.3 mm	none	none	L=9.6 mm
n= 15			n=23.3785
$\dot{Q}$ = -2233 W			$\dot{Q}$ =-2408 W

Optimum solution-Design 3

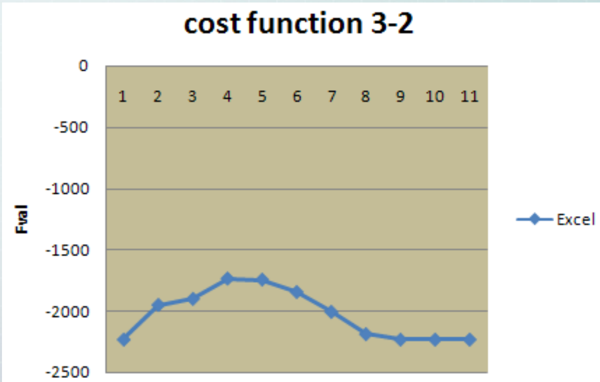
Plot iteration point – feasible region



Plot fval- feasible region



Plot fval – Infeasible region



Comparison

Existing Design

t=2.3 mm L=11 mm n=20 W= 0.9607 kg $\dot{Q}$ = 2375.58 W

2 Variables

Min cost function

$t = 2.1\,mm$

$L = 8.3\ mm$

$n = 20$

$W = 0.6548\ kg$

$\dot{Q} = 1957\ W$

Cost ↓ $\dot{Q}$ ↓

3 Variables

Min cost function

$t = 1.7\,mm$

$L = 5.6\ mm$

$n = 30$

$W = 0.5494\ kg$

$\dot{Q} = 1957\ W$

Cost ↓ $\dot{Q}$ ↓

Heat transfer

Max Heat transfer

$t = 2.3\,mm$

$L = 9.7\ mm$

$n = 23$

$W = 0.9607 kg$

$\dot{Q} = 2413.4\,W$

Cost - $\dot{Q}$ ↑

Design Proposal

Design 1 & 2

Harley Davison
35,000,000 원

Fin cost

Design 1-	Design 2-
1020원 절감	1372원 절감

Heat transfer
-418 W
Engine efficiency ↓

→ Non-optimum

Design 3

Change objective Function

Heat transfer
+38 W

→ Optimum solution

Comment

Comment

1. 핀의 가격을 낮추는 설계는 의미가 없다.
2. 열방출 최대 설계가 기존설계와 매우 비슷함
3. 최적설계효과 - 엔진 수명증가 , 고장감소
4. 알고리즘 마다 차이가 있다.
5. 대류열전달계수와 응력 부분에 대한 연구 필요


Thank You
by Cool Guys