Motorcycle Cooing Fin
Harley-Davidson

Made by Cool Guys

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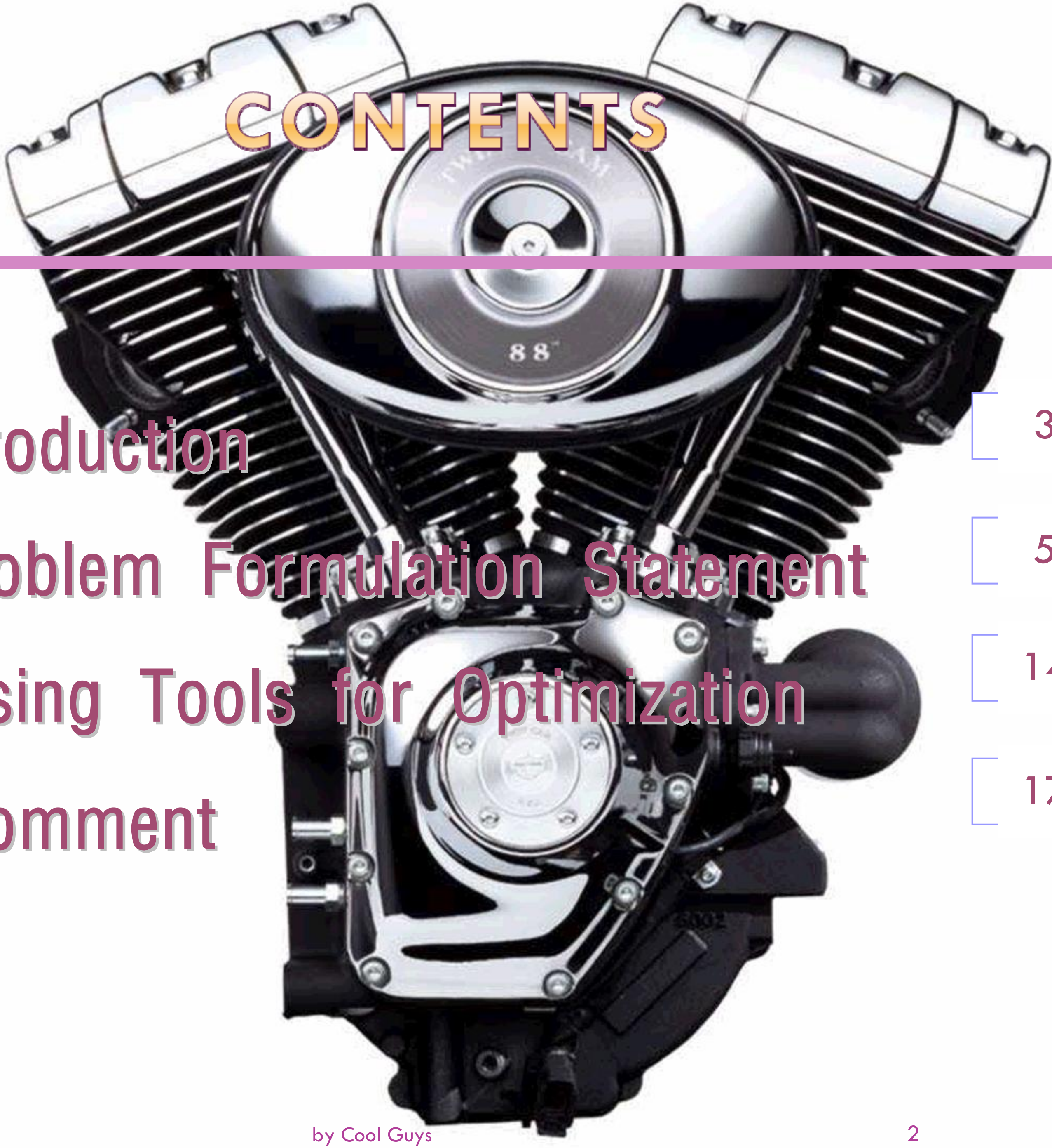
CONTENTS



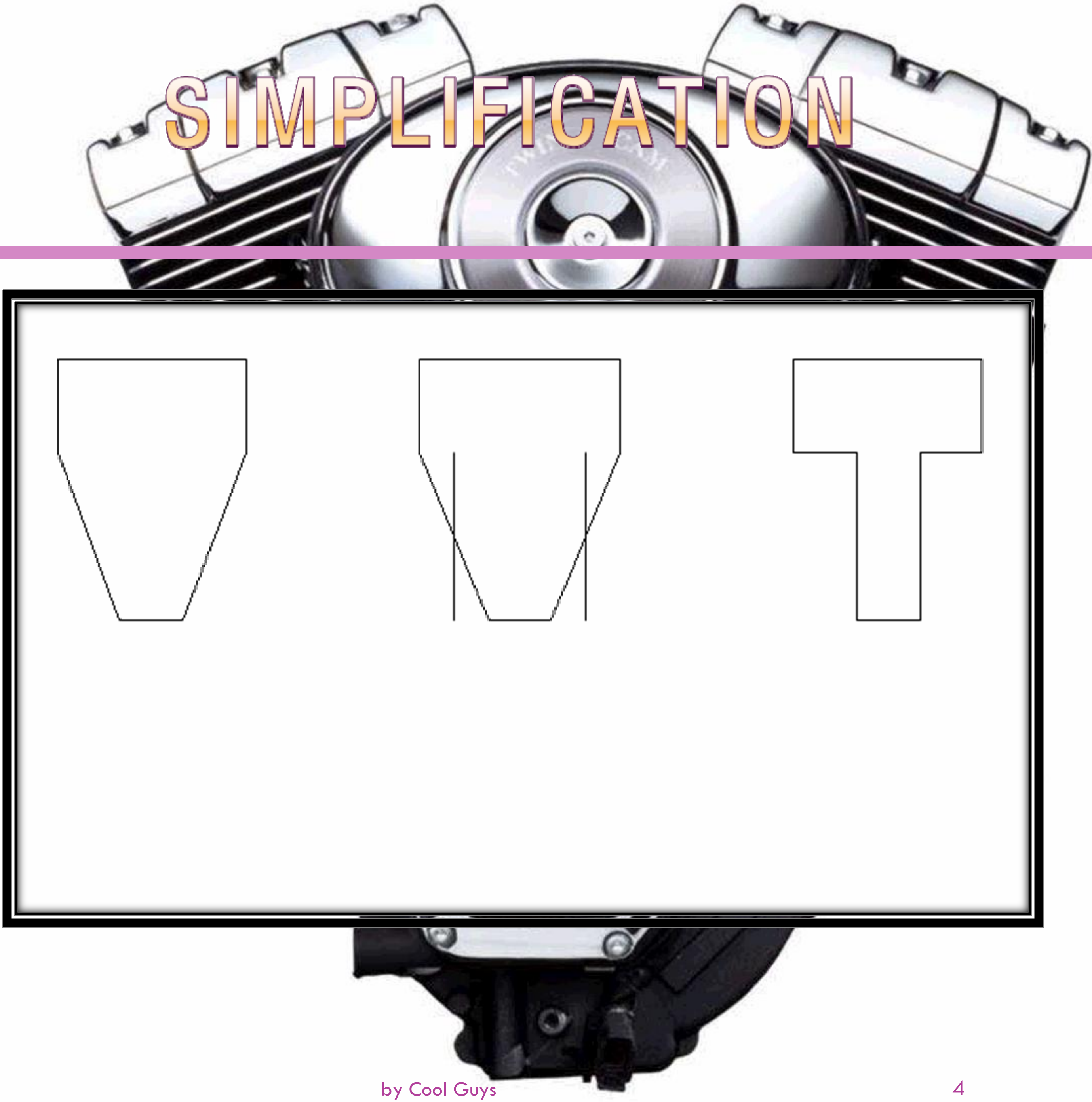
INTRODUCTION

- V-twin cam engine and cooling fin

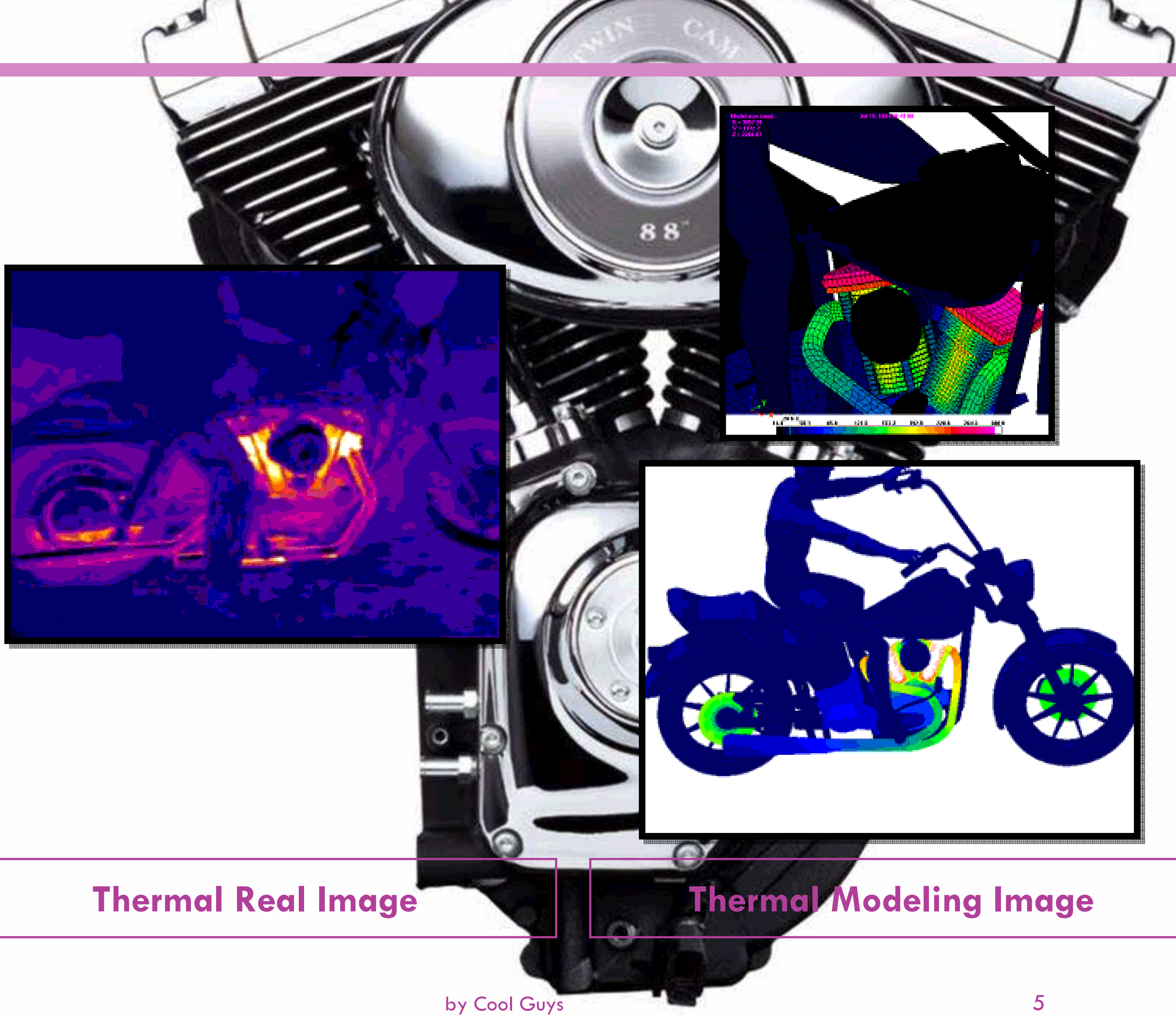
- Displacement 1450 cm^2
- Bore 95.18 mm
- Stroke 101.52 mm
- Torque 115.0nm 3000rpm

- Heat transfer in engine and fin

SIMPLIFICATION



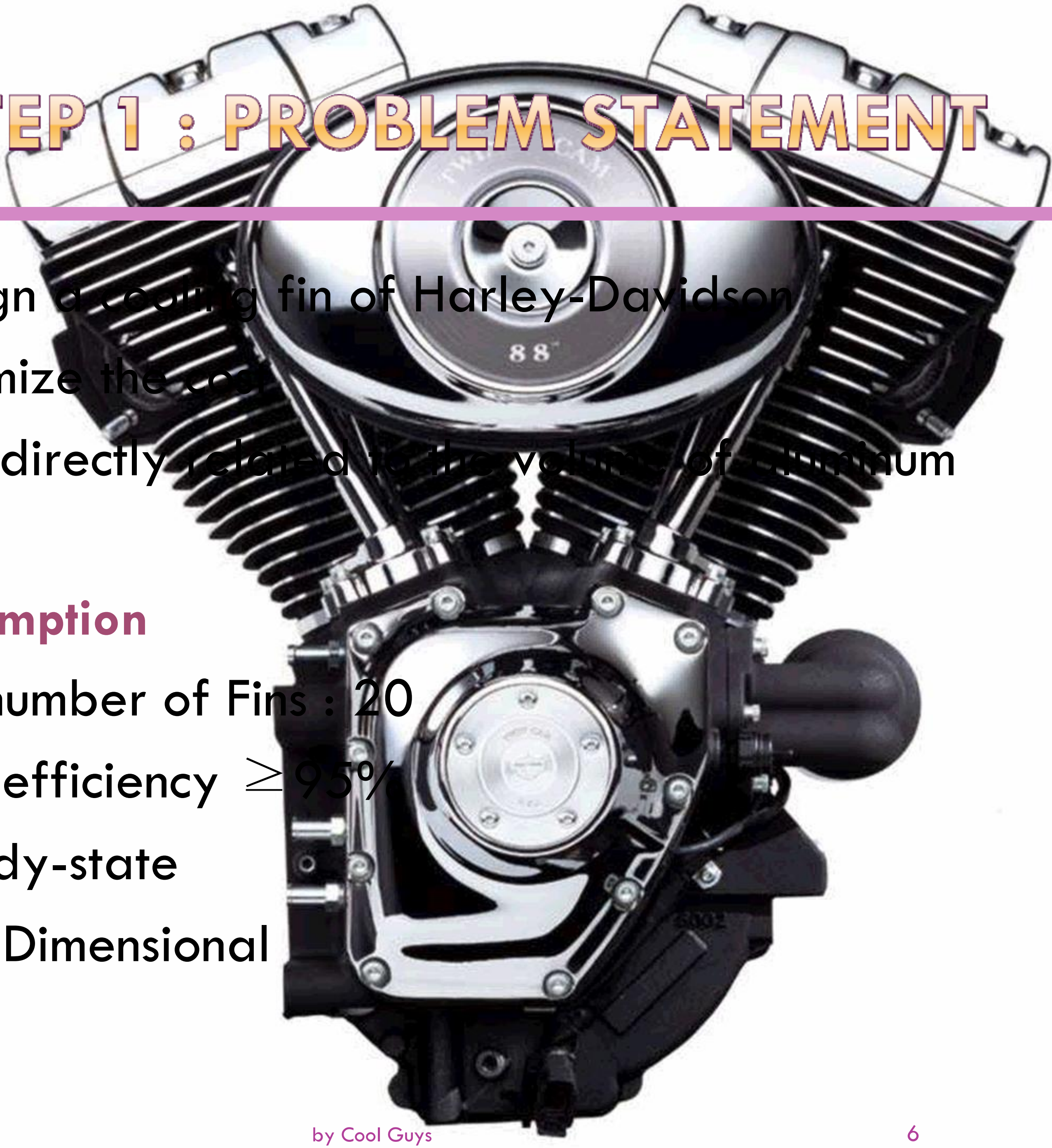
REAL & MODELING



Thermal Real Image

Thermal Modeling Image

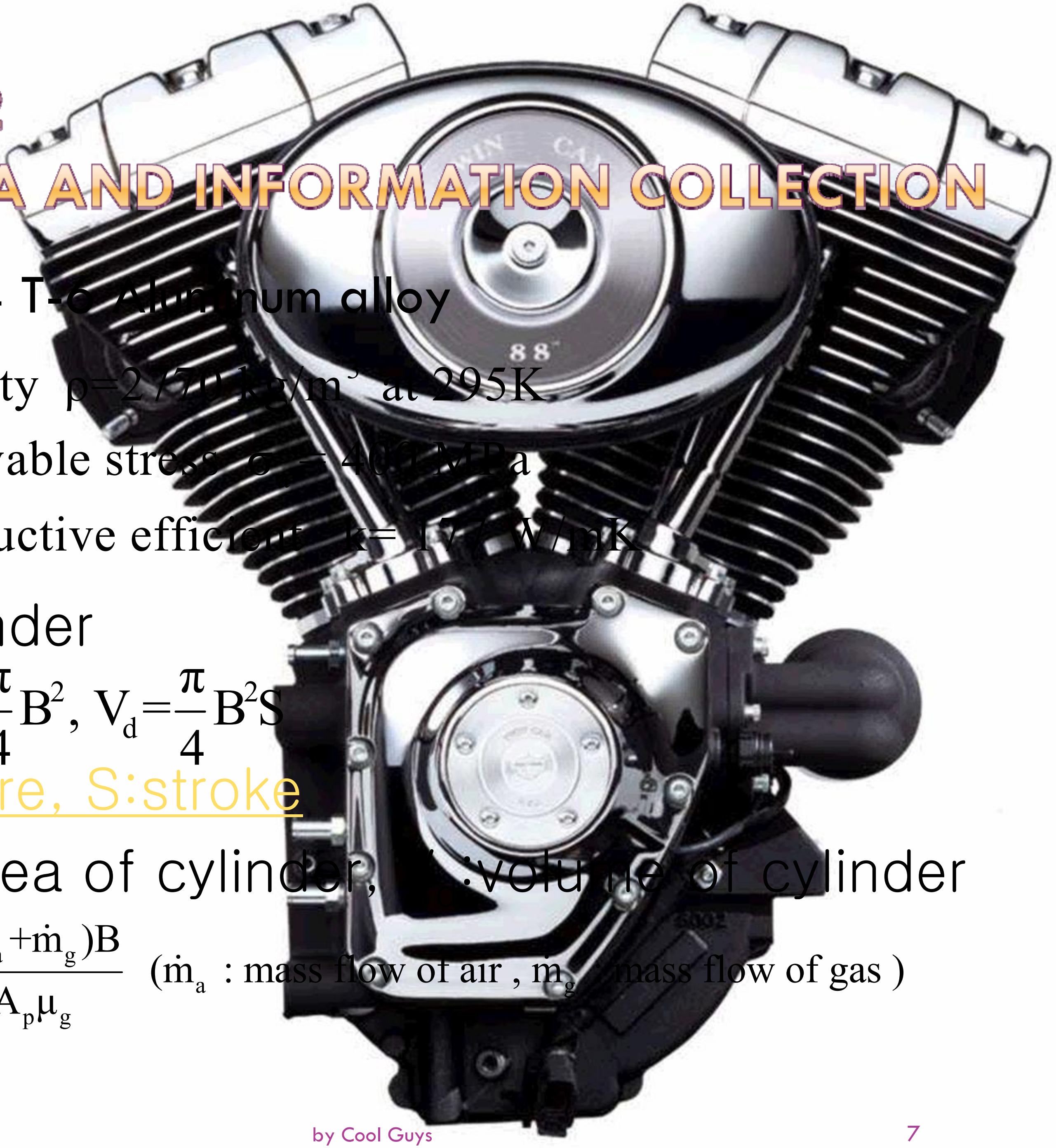
STEP 1 : PROBLEM STATEMENT



- Design a cooling fin of Harley-Davidson
- Minimize the cost
- Cost directly related to the volume of aluminum

- **Assumption**
  - The number of Fins : 20
  - Fin`s efficiency $\geq$ 95%
  - Steady-state
  - One-Dimensional

STEP 2
: DATA AND INFORMATION COLLECTION



- 2024 T-6 Aluminum alloy

  Density $\rho = 2770\ kg/m^3$ at 295K

  Allowable stress $\sigma = 400$ MPa

  Conductive efficient $k = 177\ W/mK$

- Cylinder

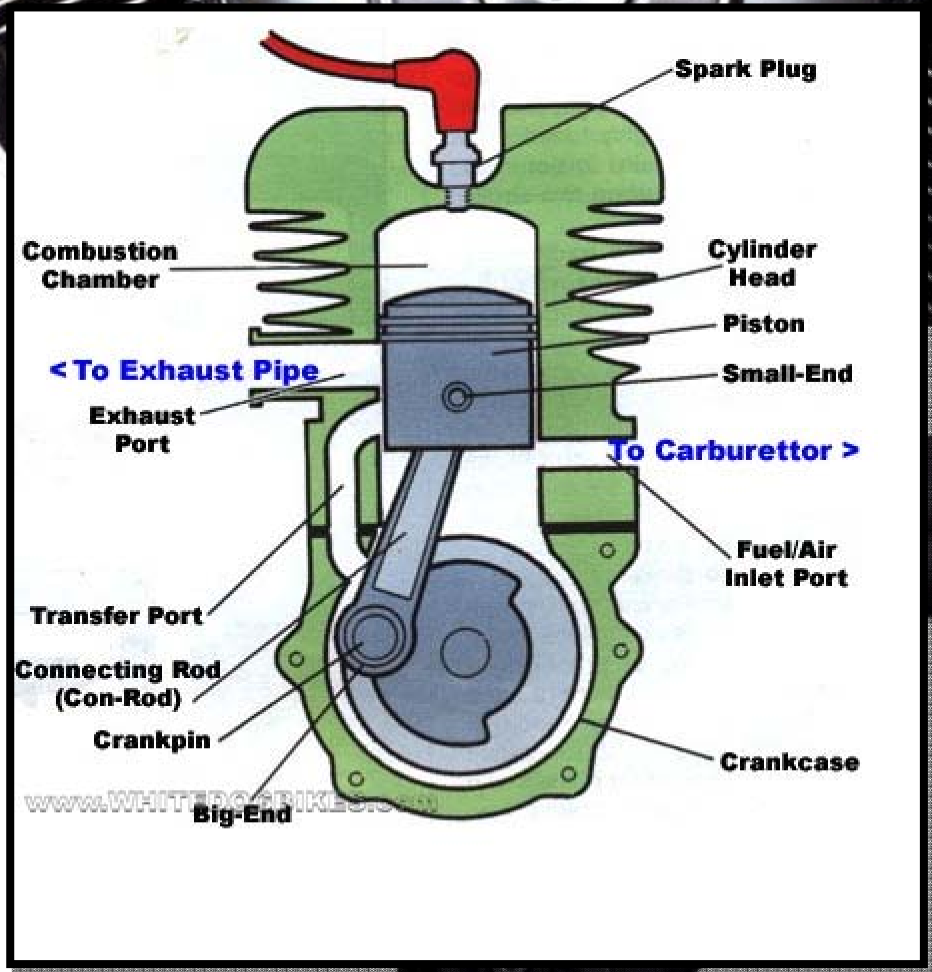
  $$A_p = \frac{\pi}{4} B^2,\ V_d = \frac{\pi}{4} B^2 S$$

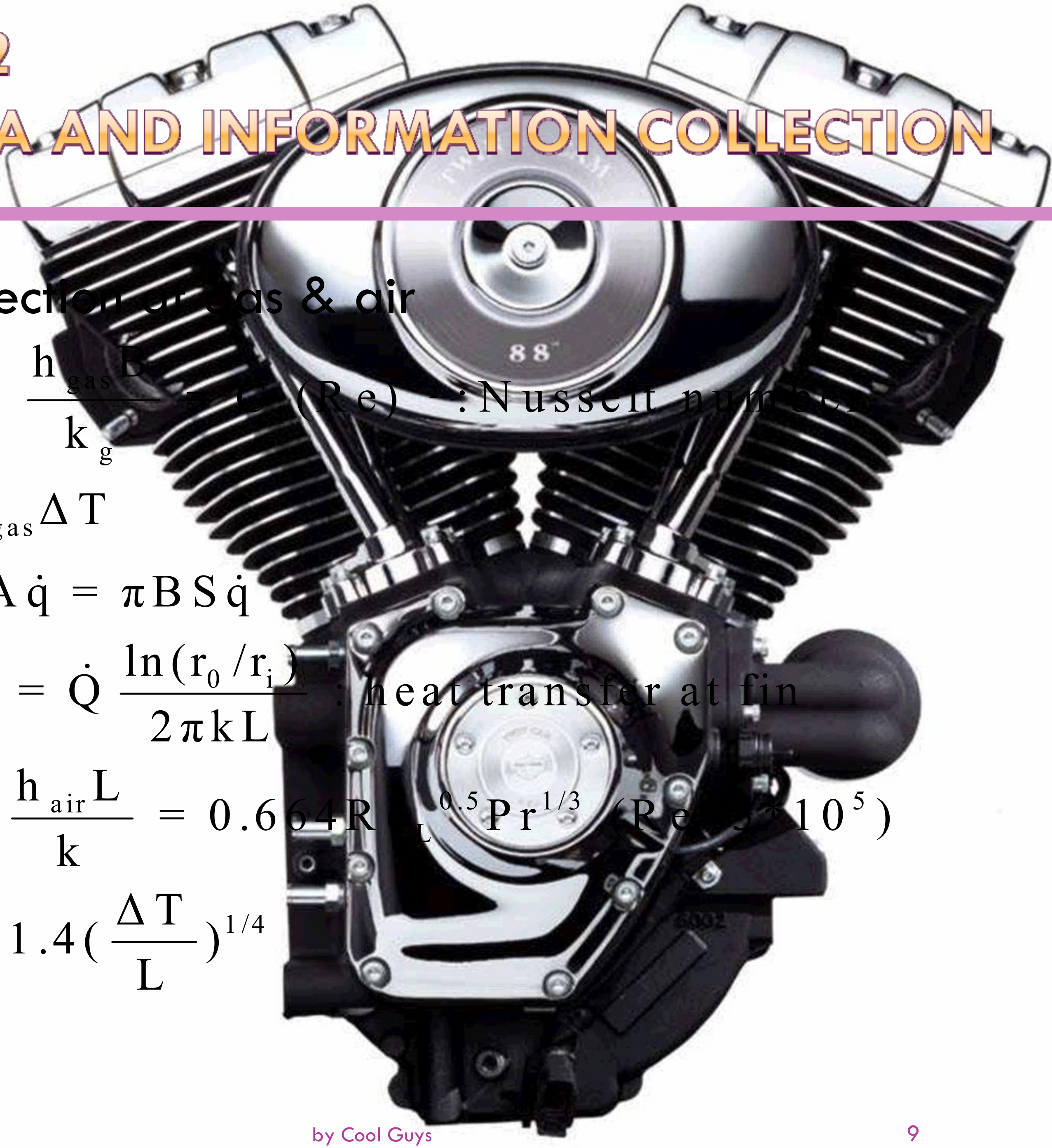
  B:bore, S:stroke

  A_p:area of cylinder, V_d:volume of cylinder

  $$Re = \frac{(\dot{m}_a + \dot{m}_g)B}{A_p \mu_g}$$ ($\dot{m}_a$: mass flow of air , $\dot{m}_g$: mass flow of gas)

CYLINDER IN ENGINE





STEP 2
: DATA AND INFORMATION COLLECTION

- Convection of gas & air

$$Nu = \frac{h_{gas} B}{k_g} = C_1 (Re) \quad : \text{Nusselt number}$$

$$\dot{q} = h_{gas} \Delta T$$

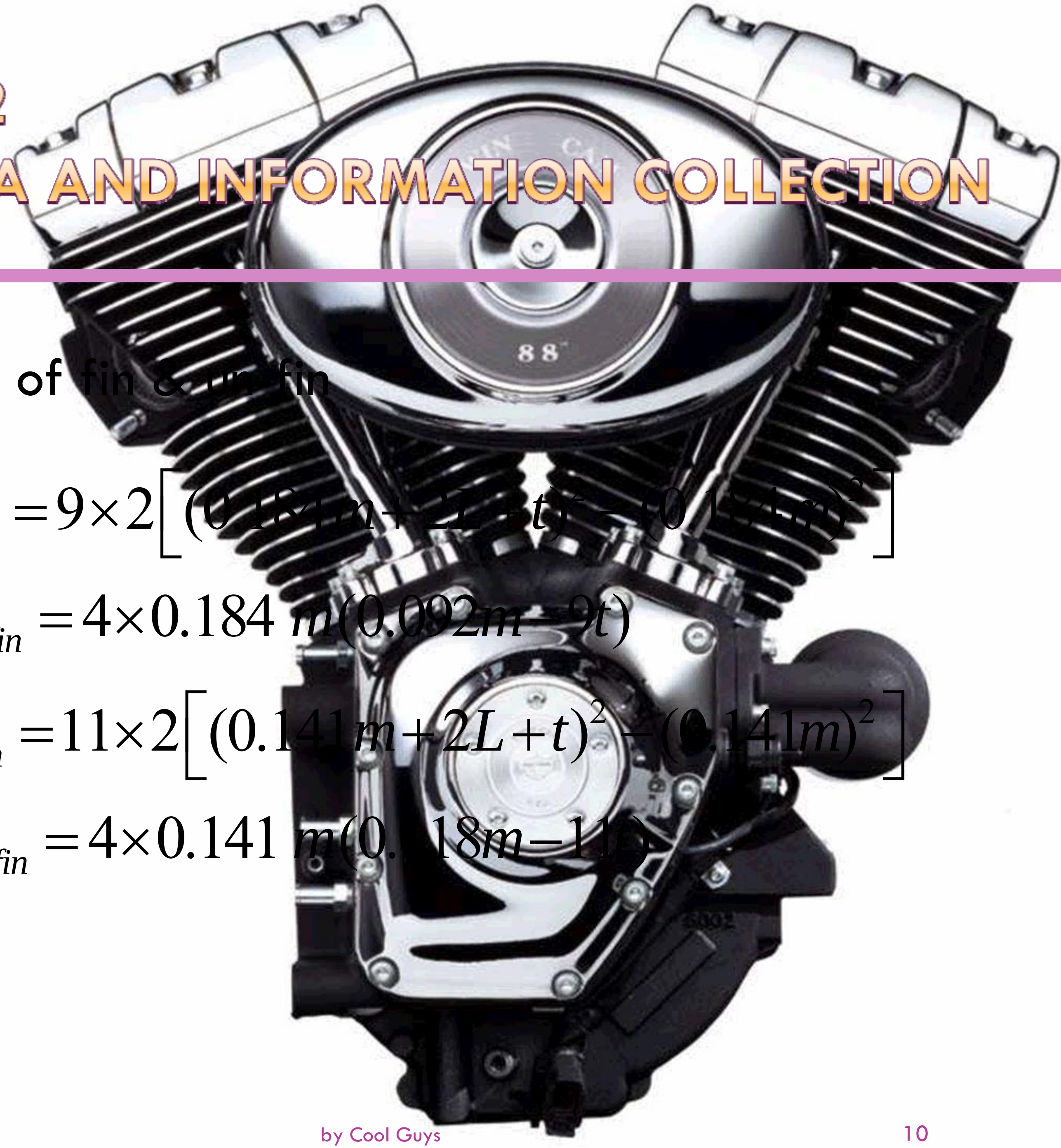
$$\dot{Q} = A \dot{q} = \pi B S \dot{q}$$

$$T_o - T_i = \dot{Q} \frac{\ln(r_0 / r_i)}{2 \pi k L} \quad : \text{heat transfer at fin}$$

$$Nu = \frac{h_{air} L}{k} = 0.664 Re_L^{0.5} Pr^{1/3} \quad (Re < 5 * 10^5)$$

$$h_{free} = 1.4 \left(\frac{\Delta T}{L} \right)^{1/4}$$

STEP 2 : DATA AND INFORMATION COLLECTION



- Area of fin & unfin

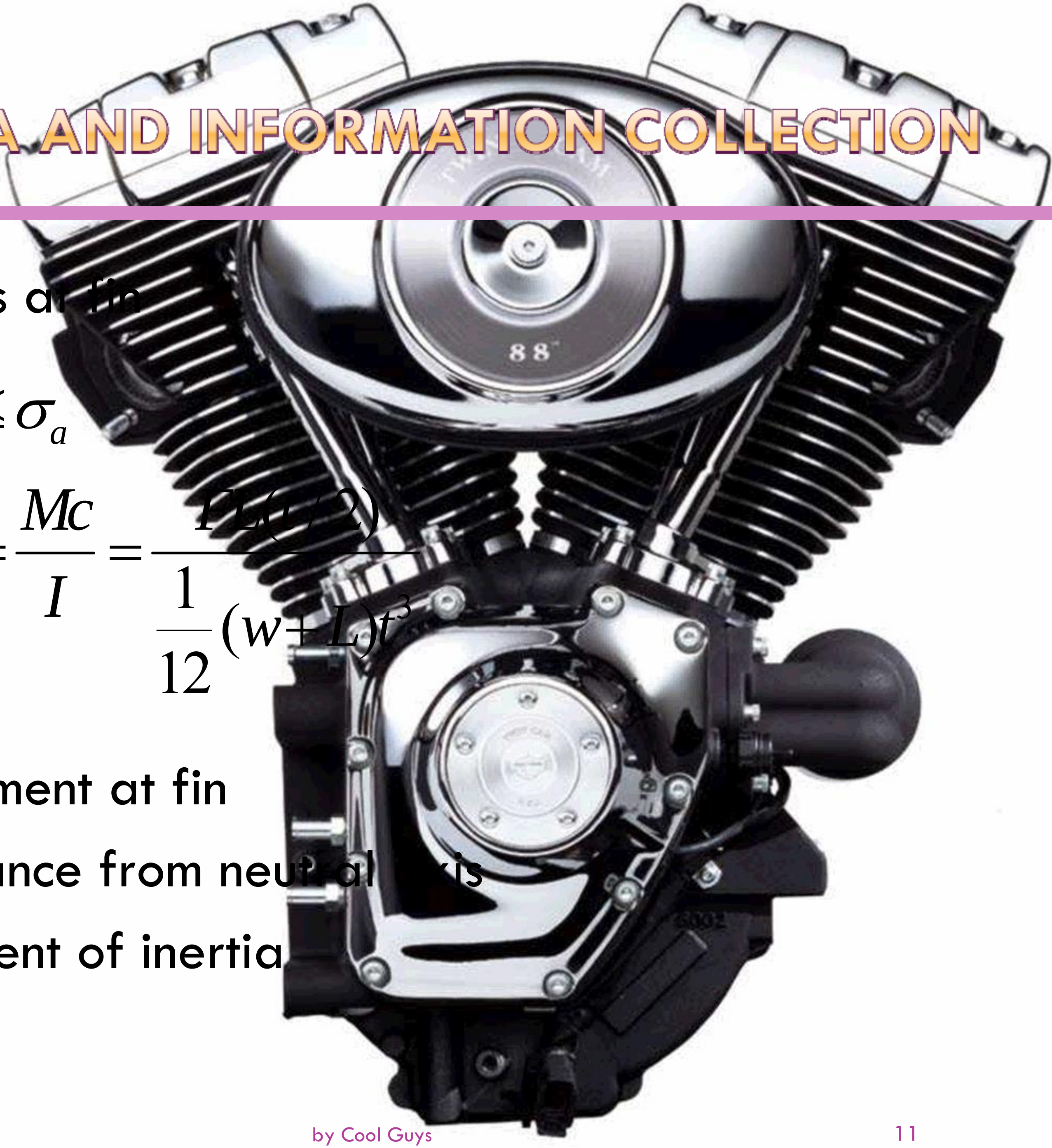
$$A_{1-fin} = 9 \times 2\left[(0.184m + 2L + t)^2 - (0.184m)^2\right]$$

$$A_{1-unfin} = 4 \times 0.184\, m(0.092m - 9t)$$

$$A_{2-fin} = 11 \times 2\left[(0.141m + 2L + t)^2 - (0.141m)^2\right]$$

$$A_{2-unfin} = 4 \times 0.141\, m(0.\text{[illegible]}18m - 11t)$$

STEP 2
: DATA AND INFORMATION COLLECTION



- Stress at fin

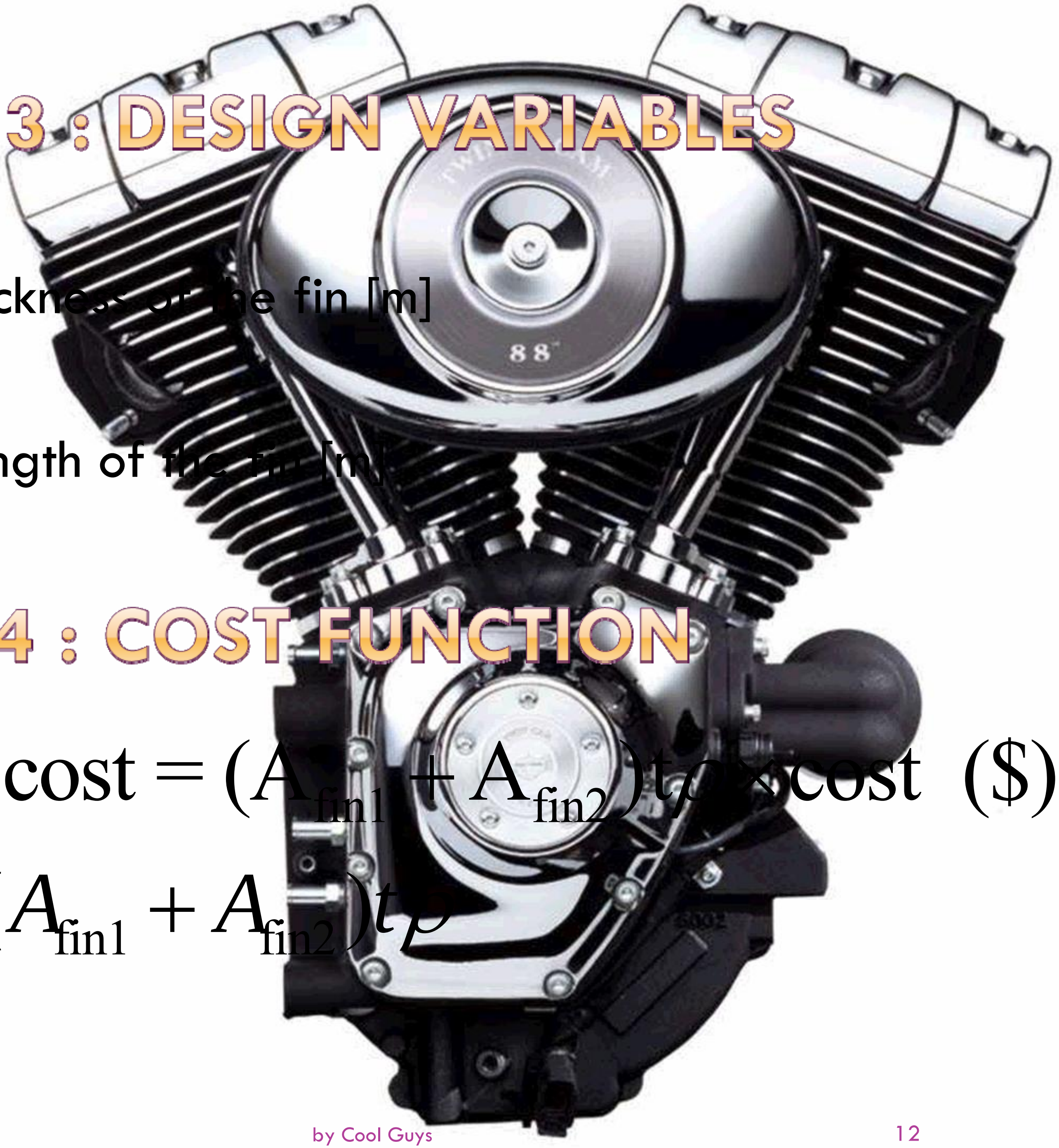
$$\sigma_{fin} \le \sigma_a$$

$$\sigma_{fin} = \frac{Mc}{I} = \frac{FL(t/2)}{\frac{1}{12}(w+L)t^3}$$

M : moment at fin

c : distance from neutral axis

I : moment of inertia



STEP 3 : DESIGN VARIABLES

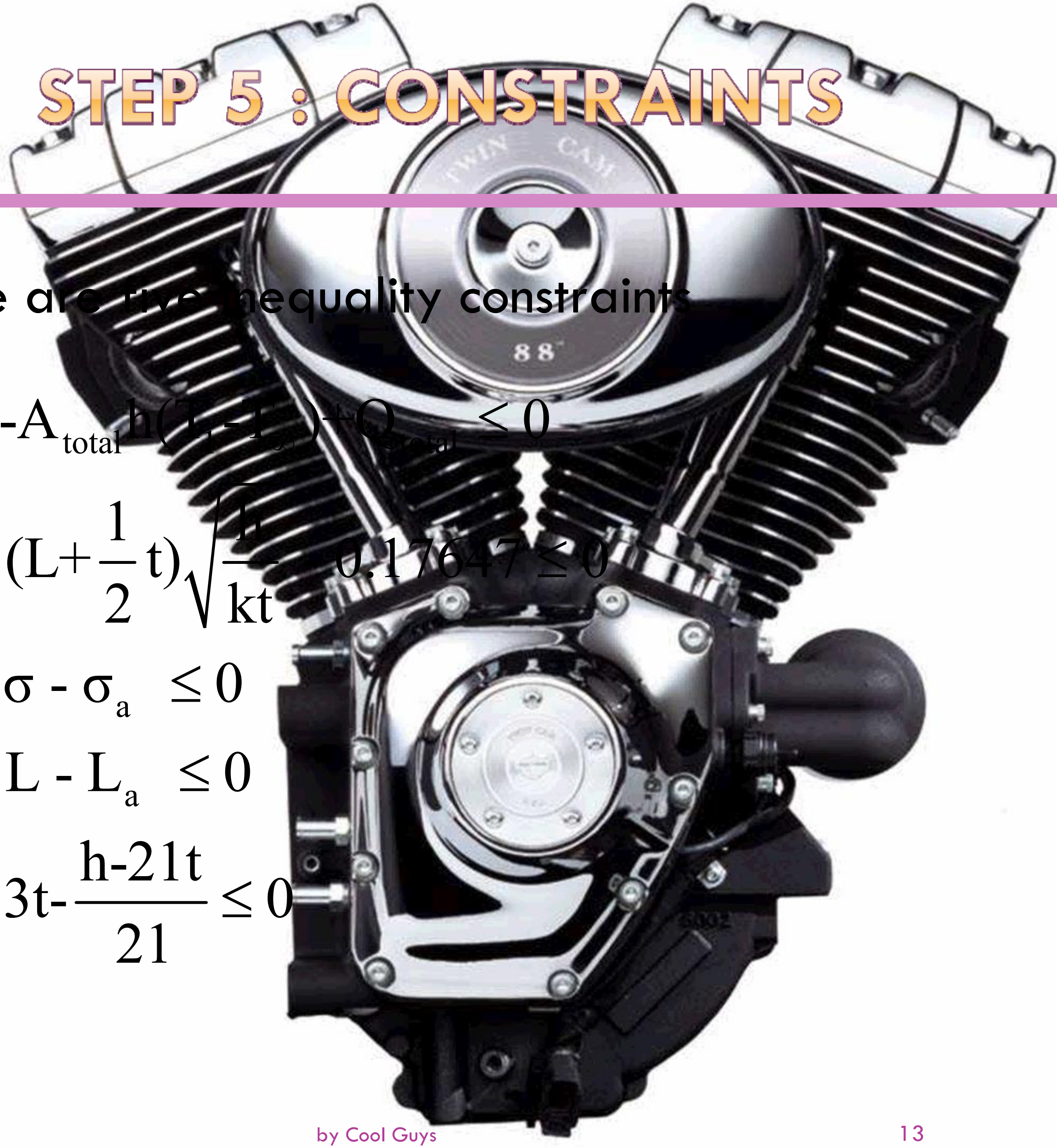
- t : thickness of the fin [m]
- L : length of the fin [m]

STEP 4 : COST FUNCTION

$$\text{total cost} = (A_{\text{fin1}} + A_{\text{fin2}})t\rho \times \text{cost} \ \ (\$)$$

$$f = (A_{\text{fin1}} + A_{\text{fin2}})t\rho$$

STEP 5 : CONSTRAINTS



- There are five inequality constraints

$$g_1 : -A_{total} h(T_1 - T_{air}) + Q_{total} \le 0$$

$$g_2 : (L + \frac{1}{2} t)\sqrt{\frac{h}{kt}} - 0.17647 \le 0$$

$$g_3 : \sigma - \sigma_a \le 0$$

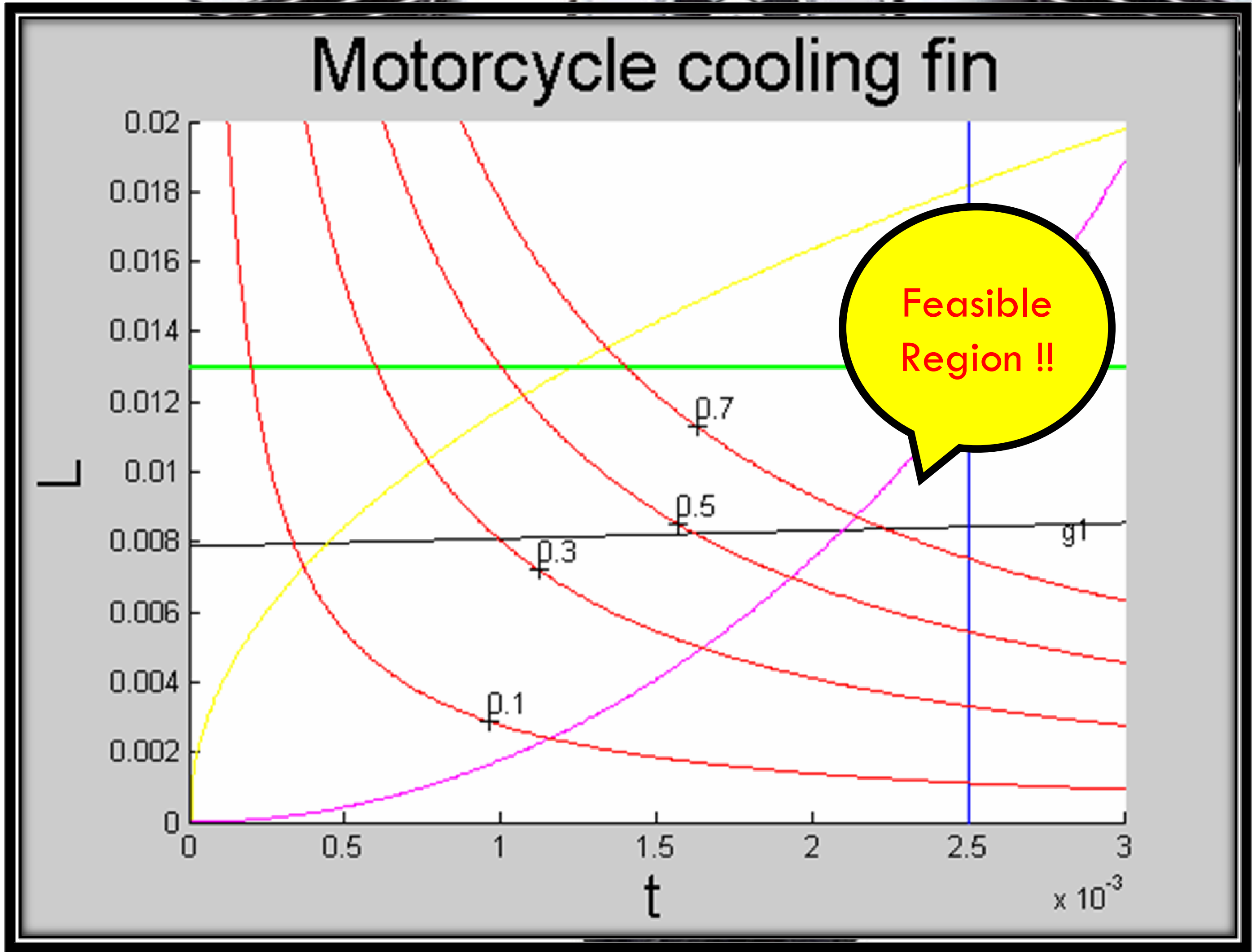
$$g_4 : L - L_a \le 0$$

$$g_5 : 3t - \frac{h-21t}{21} \le 0$$

USING MATLAB-SOURCE

```
>> [t,L]=meshgrid(0:0.00001:0.003,0:0.0001:0.02);
a=0.184;
b=0.141;
t1=183.3;
t2=185.5;
ti=25;
h=36.6;
f=2770.*(9.*((a+2.*L).^2-a^2)+11.*((b+2.*L).^2-b^2)).*t;
g1=-(18.*((a+2.*L+t./2).^2-a^2)*0.95+4*a.*(0.092-9.*t))*h*(t1-ti)-(22.*((b+2.*L+t./2).^2-b^2)*0.95+4*b.*(0.118-11.*t))*h*(t2-ti)+1957;
g2=(L+t./2).*sqrt(h./(177.*t))-0.17647;
g3=42379.*L./((0.184+2.*L).*t.^2)-400000000;
g4=L-0.013;
g5=4.*t-0.01;
cla reset
axis auto
hold on
xlabel('t','fontsize',20'),ylabel('L','fontsize',20')
title('Motorcycle cooling fin','fontsize',25')
hold on
cv=[0 0.00001];
const1=contour(t,L,g1,cv,'k');
const2=contour(t,L,g2,cv,'y');
const3=contour(t,L,g3,cv,'m');
const4=contour(t,L,g4,cv,'g');
const5=contour(t,L,g5,cv,'b');
fv=[0.1 0.3 0.5 0.7];
fs=contour(t,L,f,fv,'r');
clabel(fs)
text(0.0028,0.016,'g3')
text(0.0028,0.0083,'g1')
>> |
```

USING MATLAB(GRAPH)



USING MATLAB(SOLVER)

- Determine initial value from the graph

```
>> %그래프를 보고 초기값 [0.002,0.008] 로 정함;
>> x0=[0.002,0.008];
>> x=fmincon('func',x0,[],[],[],[],[],[],'const')
```

- The value of t & L

```
x =

    0.0021    0.0083
```

- Minimum Volume

```
>> f=2770*(9*((a+2*0.0083)^2-a^2)+11*((b+2*0.0083)^2-b^2))*0.0021

f =

    0.6514
```

COMMENT & REFERENCE

- Comment

① 기존 모델의 형상을 그대로 따라가진 못했지만 핀의 무게와 높이 사이 거의 비슷한 값으로 나왔다.

② 그래프를 보고 대략적인 최소값을 예측할 수 있었고 MATLAB의 fminction기능을 이용하여 최소가 되는 값을 확인할 수 있었다.

③ 대류열전달 계수를 구하는데 있어서 더 엄밀한 기준이 필요하다.

④ 충격량에 대한 실험이나 해석이 부족하였다.

- Rederence

- 내연기관공학 /Pulkrabek
- Heat transfer /Yunus A cengel
- 재료역학 /Ferdinand. P Beer
- Internet -http://nospam.thermoanalytics.com/
- -http://www.totalmotorcycle.com/
- -http://www.harley-davidson.com/ 등등
- 2004 년도 김동완/ 박상인-김강원 project 참고