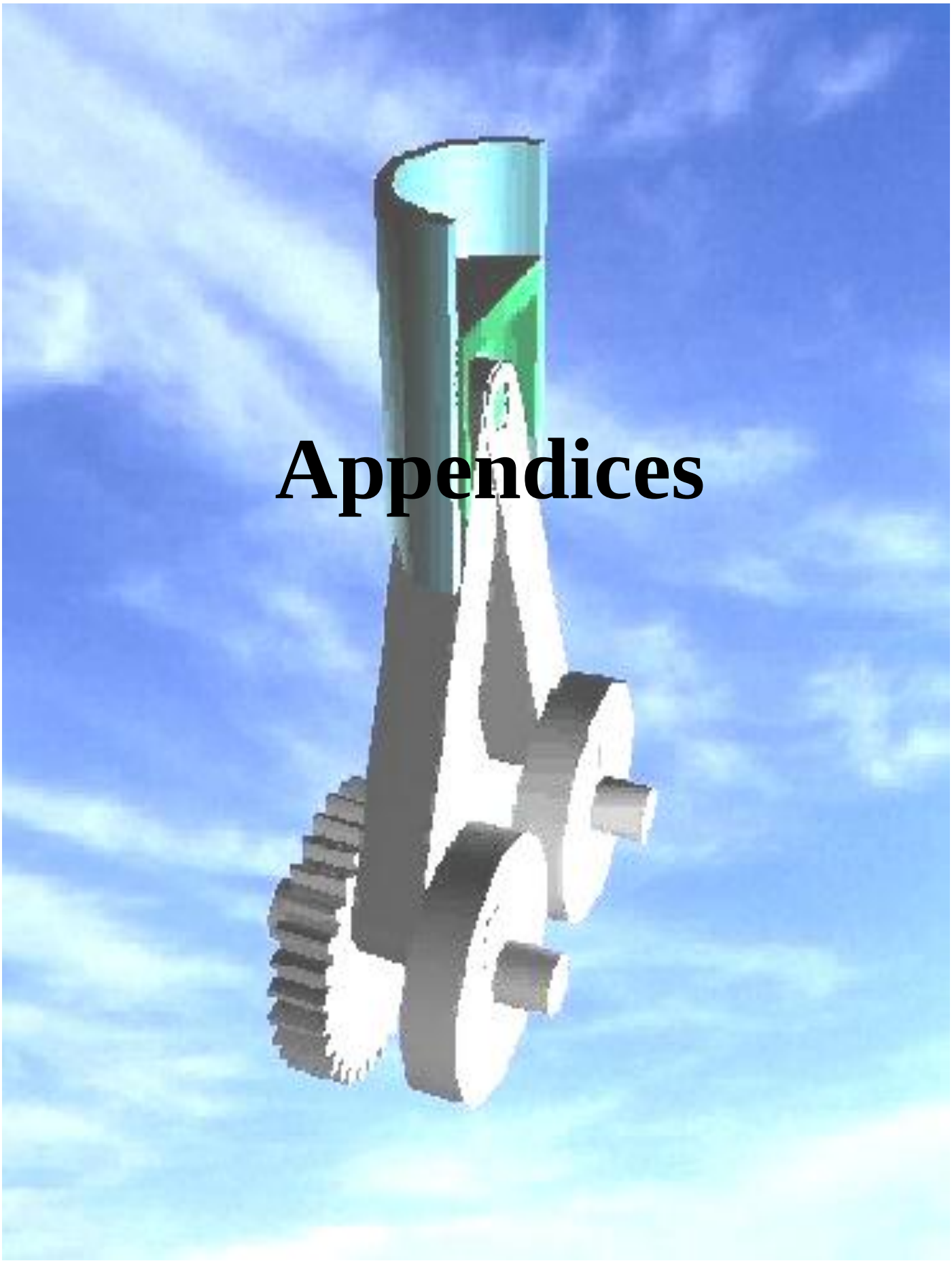

Appendices

Appendices A

FORTRAN program used for calculating piston displacement, speed, acceleration and the angle φ, with an offset crankshaft engine:

```
program acceleration
integer i
i = 0
omega = 55
r = 0.02
do while (r < 0.03)
d = 0
do while (d < 0.03)
b = 0.08
do while (b < 0.1)
do 1 I = 0,361
theta=i*3.142857143/180.0
s=r*cos(theta)+sqrt((b**2)-(r*sin(theta)+d)**2)
v=r*w*sin(theta)+(2*(r*sin(theta)+d)*r*w**cos(theta))
&/sqrt((b**2)-(r*sin(theta)+d)**2)
a=-r*cos(theta)*(w**2)
a1=(((r*sin(theta)+d)**2)*(r**2)*((cos(theta))**2)*(w**2))
a2=(sqrt((b**2)-(r*sin(theta)+d)**2))**3
a3=(r*sin(theta)+d)*r*sin(x)*(w**2)-(w**2)*(r**2)*(cos(theta))**2
a4=sqrt((b**2)-(r*sin(theta)+d)**2)
a5=a-(a1/a2)+(a3/a4)
phi=asin((d+r*sin(x))/b)
write i,s,a5, v,phi
1    continue
b = b+0.01
end do
d = d+0.01
end do
r = r +0.005
end do
end
```

Appendices B

FORTRAN program used to get the inline engine performance:

```
program inlinecrankshaft engine
integer i
omega =constant
r = 0.023
b = 0.092
m = 0.441
pi =3.141592654
do 10 I = 0,360
theta = i*pi/180
F=196.6*cos((pi/2)-(theta+asin((r*sin(theta))/b)))*cos(asin((r*sin(theta))/b))
a=r*(w**2)*(cos(theta)+(cos(2*theta))/(2*(b/r)))
if(i.le.180)  N=F-a*m+m*9.81
if(i.gt.180)  N=F-a*m-m*9.81
Fthrust =196.6*cos((pi/2)-(theta+asin((r*sin(theta))/b)))*((r*sin(theta))/b)

Write N, Fthrust, a
10    continue
end
```

Appendices C

FORTRAN program to calculate the offset crankshaft engine performance

```
program offsetcrankshaft
integer i
omega = 55
r = 0.023
b = 0.16
d = 0.045
do 1 i = 0,361
theta = i*3.142857143/180.0
a = -r*cos(theta)*(w**2)
a1=(((r*sin(theta)+d)**2)*(r**2)*((cos(theta))**2)*(w**2))
a2=(sqrt((b**2)-(r*sin(theta)+d)**2))**3
a3=(r*sin(theta)+d)*r*sin(theta)*(w**2)-w**2)*(r**2)*(cos(theta))**2
a4=sqrt((b**2)-(r*sin(theta)+d)**2)
a5=a-(a1/a2)+(a3/a4)
F=2*(98.289*cos(90-asin((d+r*sin(theta))/b)+theta))
F2=cos(asin((d+r*sin(theta))/b))
phi=asin((d+r*sin(theta))/b)
F1= m *a5
N=F*F2-F1
Fthrust= F*((d+r*sin(x))/b)
if (i.ge.185) N = F3+7.135
if (i.lt.185) F3 = F3-7.135
write(3,8) N, Fthrust
1       continue
        End
```

Appendices D

FORTRAN program to calculate the twin crankshaft engine performance

```
      program twincrankshaft
      integer i
      i = 0
      omega = 55
      r = 0.023
      b = 0.16
      d = 0.045
      do 1 i = 0,361
      theta = i*3.142857143/180.0
      a = -r*cos(theta)*(w**2)
      a1=(((r*sin(theta)+d)**2)*(r**2)*((cos(theta))**2)*(w**2))
      a2=(sqrt((b**2)-(r*sin(theta)+d)**2))**3
      a3=(r*sin(theta)+d)*r*sin(theta)*(w**2)-(w**2)*(r**2)*(cos(theta))**2
      a4=sqrt((b**2)-(r*sin(theta)+d)**2)
      a5=a-(a1/a2)+(a3/a4)
      F=2*(98.289*cos(90-asin((d+r*sin(theta))/b)+x))
      F2=cos(asin((d+r*sin(theta))/b))
      phi=asin((d+r*sin(theta))/b)
      F1=0.68621 *a5
      N= F*F2-F1
      if (i.ge.185) N=N+7.135
      if (i.lt.185) N=N-7.135
      write(3,8) N
1     continue
      End
```

Appendices E

Numerical solution of ordinary differential equations

This program advanced the solution of first order differential equations of the form dx/dt=f(x) using the Runge-Kutta fourth order method.

```
      PROGRAM PRK4TH
      REAL FCN,TO,XO,H,TF,X
      EXTERNAL FCN
      READ *,TO,XO,H,TF
      PRINT 200
      PRINT 201,TO,XO

5     CALL RK4TH(FCN,TO,H,XO,X)
      TO=TO+H
      XO=X
      PRINT 201,TO,X
      OPEN(3,FILE ='RESULT.DAT')
      WRITE(3,*)X
      IF (TO.LT.TF) GOTO 5

200   FORMAT (///'SOLUTION TO A DIFFERENTIAL EQUATION',/'
     &     BY RK4TH METHOD',
     &     //5X,'T',13X,'N',//)
201   FORMAT (1X,F8.2,1X,F14.3)
      STOP
      END

      REAL FUNCTION FCN(XN,T)
      REAL XN,T
      gamma =1.3
      thetas =-40
      r =10
```

```
      thetab =40
      en =4
      vol= (1+(r-1)/2*(1-cos(t)))/r
      dvol=(r-1)/2*sin(t*3.14/180)/r*3.14/180
      dxx=0
      IF (t.LT.thetas) GOTO 10
      xx=1-EXP(-((t-thetas)/thetab)**en)
      dxx=(1-xx)*en*((t-thetas)/thetab)**(en-1)/thetab
10    FCN = -gamma*xn*dvol/vol+(gamma-1)*40*dxx/vol
      RETURN
      END

      SUBROUTINE  RK4TH(FCN,TO,H,XO,X)
      REAL  FCN,TO,H,XO,X,XK1,XK2,XK3,XK4
      XK1= H*FCN(XO,TO)
      XK2 = H*FCN(XO+XK1/2.0,TO+H/2.0)
      XK3 = H*FCN(XO+XK2/2.0,TO+H/2.0)
      XK4 = H*FCN(XO+XK3,TO+H)
      X = XO+(XK1+2.0*XK2+2.0*XK3+XK4)/6.0
      RETURN
      END
```

Appendices F

Papers published during the course of present work