

catool

Combustion Analysis TOOL

User Guide

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catool (www.catool.org)
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Introduction

Catool is an open-source software package designed to post-process cylinder pressure data collected from an internal combustion engine. As well as calculating standard thermodynamic calculations such as pressure rise rates, heat transfer and knock metrics, it deals with the format conversion, absolute pressure referencing, error detection and correction required for robust data analysis.

Catool can import raw combustion data from the industry standard AVL I-File format as well as ASCII text files, allowing the flexibility to use off-the-shelf data acquisition systems such as those from National Instruments and Measurement Computing, to standard combustion systems such as AVL Indiscope and ADAPT CAS.

Catool has been designed to be fast, flexible and capable of simple modification to suit a range of combustion analysis tasks. Its primary limitation is that of available memory, it does not have built-in limitations on the number of channels or lengths of data acquisition. Its smallest working resolution of 1/20 of a degree matches that of industry standard systems and can be increased if necessary.

Downloading and Installation

The latest version of catool can be downloaded from www.catool.org. It is available both as source code for compilation on Unix type operating systems or pre-compiled binaries for Microsoft Windows.

By providing source code, catool can be compiled to run on almost any operating system and can easily be modified to suit particular purposes.

By providing pre-compiled binaries for Microsoft Windows, most users can be up and running in a matter of minutes.

Source code and Compiling

If you wish to install catool out-of-the-box on a Microsoft Windows platform you can skip to the Binary Installation section.

Compiling in a UNIX environment

Replace the # with the latest version number of catool:

```
mkdir /usr/src/catool-0.9.#
cd /usr/src/catool-0.9.#
wget http://catool.org/cgi-bin/download?catool-0.9.#-src.zip
unzip catool-0.9.#-src.zip
make clean
make
```

catool should now be built. Check by running

```
./catool
```

You should see the following output

```
Usage: catool [-h] [--debug-level=<debug_level>] file
```

Binary Installation

Once you have compiled or downloaded the catool binary this needs to be copied to a suitable working directory. On a UNIX platform this could be perhaps `/usr/bin`, on a Windows platform `C:\catool`. In a Windows environment you need to copy both the `catool.exe` and `pthreadGC2.dll` files to your computer.

Background

Crank Angle Domain

Unlike most traditional data analysis, combustion analysis is performed in the crank angle domain.

Data can be stored using up to five variable resolutions through an engine cycle. This minimises storage and processing, so for example, data can be stored at 1 degree resolution for the intake and compression strokes, 0.2 degree resolution for the first 40 degrees of the expansion stroke and the remaining at 1 degree resolution. A high resolution in this case enables robust knock detection.

Catool uses the following nomenclature regarding crank angles:

Degrees – number of degrees from intake TDC, therefore:

Intake stroke - 0 to 180 degrees

Compression stroke – 180 to 360 degrees

Expansion stroke – 360 to 540 degrees

Exhaust stroke – 540 to 720 degrees

Note this is different from the AVL nomenclature of -360 degrees at the start of the intake stroke and +360 degrees at the end of the exhaust stroke.

theta – these are units of the lowest resolution supported by catool. As standard this is compiled as $1/20^{\text{th}}$ of a degree. For a four stroke engine cycle theta therefore ranges from 0 to 14400 (720 degrees * 20 theta/degree).

crank_angle – data referenced in the crank_angle domain is in sequential order. This is important to understand when the crank angle abscissa has multiple measurement tables. For simple 1 degree resolution data crank_angle would range from 0 to 720. For data with a multiple resolution abscissa, for example 0 to 360 degrees @ 1 degree resolution, 360 to 400 degrees @ 0.2 degree resolution and 400 to 720 degrees @ 1 degree resolution there would be 880 crank_angle data points.

Cycles

Crank angle data is stored for a number of engine cycles. One cycle being two revolutions for a four stroke engine.

Catool's analysis is stored either in the crank angle domain, such as mean gas temperature and on a cyclic based, such as peak mean gas temperature. Catool also calculates statistics based over the entire set of engine cycles.

Configuration file

Catool is a command line driven program using a configuration file to configure the file input/output and analysis to be run. The configuration file is in text format and can be edited using Notepad or WordPad in Windows.

Usage

Catool is invoked from the command line.. This is either the Windows or UNIX command prompt .

Windows

Open the command prompt by opening Start, All Programs, Accessories, Command Prompt.

```
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.
```

```
C:\>cd catool
```

```
C:\catool>catool rover_v8_csv.ccf
```

```
Combustion Analysis Tool (catool)
Copyright (C) Ben Brown, 2000-2009
Version 0.9.7
www.catool.org
```

```
catool      incorporates      code      from      Pthreads-win32
(sourceware.org/threads-win32)
Copyright (C) 1998 John E. Bossom
Copyright (C) 1999,2006 Pthreads-win32 contributors
```

```
Config File: rover_v8_csv.ccf
Debug level: NOTICE
Set input filetype to CSV
Set input abscissa type to CRANK_ANGLE
[cut]
```

```
Analysis complete
```

```
C:\catool>
```

Examples

The following examples use some combustion data recorded from a Rover V8 engine. The raw data is available at <http://sourceforge.net/projects/catool/files/sample-data/rover-v8/roverv8-2000rpm-wot.zip/download>.

Rover V8 CSV – Load, Analyse, Save

Download the example configuration from http://catool.org/files/rover_v8_csv.ccf.

Rover V8 AVL – Load, Analyse, Save

Download the example configuration from http://catool.org/files/rover_v8_avl.ccf. This uses the AVL I-File generated in the above CSV example.

Rover V8 AVL – Load, Save as MATLAB

Download the example configuration from http://catool.org/files/avl_matlab.ccf.

Reference

The following are valid parameters in the catool configuration file:

```
debug-level DEBUG | NOTICE | WARNING | ERROR | FATAL | SILENT
```

```
input-file <filename>
```

```
input-file-type ( IFILE | CSV )
```

```
input-abscissa-type ( CRANK_ANGLE | CYCLE | TIME )
```

```
input-data ( CA | TIME | RTP_RESULTS | RESULTS | ALL )
```

```
number_of_channels <n>
```

```
number_of_cycles <n>
```

```
resolution <n>
```

```
recording-length <n>
```

```
header-lines <n>
```

```
load-channels ( n | none | all )
```

```
channel <channel_number> ( name | description | units | calibration_multiplier | calibration_adder | tdc_offset | filtering_type | cylinder | type ) <n>
```

Valid channel types: ENG_SPEED, CYLPR, INJPR, NEEDLELIFT, VALVELIFT, INLETPR, EXHPR, LOWT, HIGHT, SPKPRICURR, SPKSECCURR, BLOCKACC, IGNANG, CPS, CID, INJECTOR, TIME.

```
engine ( name | evo_ca | ivc_ca | bore | stroke | conrod_length | pin_offset | pin_offset_2 | compression_ratio | cylinders | strokes | type ) <n>
```

Valid engine types: SI, DISI, CI_DI, CI_IDI, SI_ROTARY

```
load-file
```

```
channel-offset ( fixed_value | offset_start_ca | offset_finish_ca | polytropic_index | calc_interval | offset_channel | offset_type ) <n>
```

Valid offset types: NONE, FIXED, POLYTROPIC, OTHER, IFILE

```
set ( comment | parameter-file | date | parameter <1-27>
| eoc_start_window | eoc_finish_window | eoc_index |
t_ivc | temp_ref_ca | mfb_n | annand_a | t_wall | R
poly_exp_start_angle | poly_exp_finish_angle |
poly_comp_start_angle | poly_comp_finish_angle |
pkp_start_angle | pkp_finish_angle | cd_start_angle |
cd_finish_angle | engine_speed | start_of_combustion
misfire_imep | slowburn_imep | knock_pkp | tla_range
wiebe_a_start | wiebe_a_finish | wiebe_a_step |
wiebe_m_start | wiebe_m_finish | wiebe_m_step |
start_of_combustion_start_window |
start_of_combustion_finish_window | engine_speed_channel
| start_of_combustion_channel | knock_integral_type |
engine_speed_type | start_of_combustion_type |
heat_release_model | heat_transfer_model ) <n>
```

Valid knock integral types: RECTIFIED_INTEGRAL, SQUARED_INTEGRAL.

Valid engine speed types: NOTHING, SPECIFY, CHANNEL_AVERAGE, AVL_RZT

Valid start of combustion types: SPECIFY, RISE_RATE, WINDOW_RISE_RATE, CHANNEL_AVERAGE, CHANNEL_AVERAGE_AVL, CHANNEL_AVERAGE_ADVANCE.

Valid heat release models: FIRST_LAW, POLY_FIRST.

Valid heat transfer models: ANNAND, WOSCHNI, HOHENBERG, EICHELBERG, NUSSELT, BRILING.

output-file <filename>

output-file-type (IFILE | CSV | MATLAB)

output-data (CA_RAW | CA | CA_TO_TIME | TIME | RTP_RESULTS | RESULTS)

```
analyse ( n | all | none | GAMMA |
GROSS_HEAT_RELEASE_RATE | H | KNOCKING_PRESSURE |
PRESSURE_RISE_RATE | MEAN_GAS_TEMP | MFB |
MOTORED_PRESSURE | MOVING_PRESSURE_AVERAGE |
NET_HEAT_RELEASE_RATE |
BURN_ANGLE_1,2,5,10,20,25,50,75,80,90,95,99 |
ENGINE_SPEED | KNOCK_INTEGRAL | EEOC | GROSS_IMEP |
```

```

LOWER_PUMPING_IMEP | MAX_BURN_RATE | MAX_BURN_RATE_CA |
MAX_HEAT_RELEASE_RATE | MAX_HEAT_RELEASE_RATE_CA |
MAX_PRESSURE_RISE_RATE | MAX_PRESSURE_RISE_RATE_CA |
MAX_PRESSURE | MAX_PRESSURE_CA | MAX_MEAN_GAS_TEMP |
MIN_PRESSURE | MIN_PRESSURE_CA | OFFSET |
PEAK_KNOCKING_PRESSURE | PEAK_KNOCKING_PRESSURE_CA |
POLY_EXP | POLY_COMP | START_OF_COMBUSTION | TLA |
TOTAL_HEAT_RELEASE | UPPER_PUMPING_IMEP | WIEBE_A |
WIEBE_M )

```

Multiple items can be specified on one line. Use of a minus sign before the analysis type negates that analysis.

Example:

```
analyse all -WIEBE_A -WIEBE_M
```

Would run all analysis except Wiebe a and m parameter calculations.

```
run-analysis
```

```
output
```

```
print <n>
```

```
stop
```

```
threads <n>
```