BIMOTION

BIMOTION ADVANCED HEAD MANUAL

Copyright © 2025 Bimotion, Ver 2.6.5
www.bimotion.se

The Bimotion Advanced Head software is copyrighted, which means that it is not allowed to be copied, loaned, cracked, changed, sold, etc.

TABLE OF CONTENTS

BIMOTION

1   INTRODUCTION

This program is intended for amateurs and professionals with at least basic knowledge from thermodynamics and high performance engines. The importance of designing an efficient cylinder head is very vital to a 2-stroke engine. Without a well working squish band, the combustion will burn slowly and inhomogeneous, which means that only a reduced amount of the charged fuel will produce useful work. In order to dimension a head the developer also needs to know how efficient the cylinder charging is from the transfer ports and the exhaust pipe. An engine could work fine with one exhaust pipe and start to detonate with another. An exhaust pipe that return stronger pulses can charge the cylinder harder at high rpm and make the gas mix detonate if the head is not modified. Nowadays it is possible to film the combustion of fuel burning inside a cylinder head in real time. Previously such measurements were studied with laser Doppler equipment in which gas movement and velocities was calculated. The difference between studying a restricted calculation model and the reality is like using your ears instead of your eyes to get the picture. But still, we need to use simple calculation models to predict the reality and get knowledge about its behavior.

The parametric design approach of this program will help the developer to try new shapes and understand the relationships in an interactive way of doing the changes.
Picture 1 shows the head from a TZ250 with a special step shaped squish band and flat roof. The different colors come from different materials and ceramic coating used for improved heat transfer and combustion. Note the sharp edges and detonation marks.

Picture 1. TZ250 head.

Additional theory can be found at the Bimotion website in the 'Theory' section.

Bimotion cooperate with the great tuning company at http://www.replikamaschinen.com south of San Francisco when it comes to high quality port work, engine machining, rebuild, restoration, etc. Highly recommended for advanced services!

2 INSTALLING, OPEN / SAVE

The program is delivered by e-mail link for download. No installation is needed, the downloaded file is the executable program. When opening the program, Excel may ask for acceptance to run macros dependent on the security settings in your PC. This program is reliable and free from virus so you should accept to run macros, otherwise the program will not work properly.

NOTE! When using Excel 2010 or later, the downloaded xls-file needs to be "unblocked" in order to run the program code. Do this: Right click the file > choose "Properties" > in the "General" tab ,click the check box "Unblock" > click OK.

If you have trouble with this setting then see the troubleshoot section.

Information about historical changes can be found at www.bimotion.se in the Cylinder Head page. The program checks for new available versions when the "About…" sheet is activated and notifies the status.

3 A FIRST VIEW

3.1 Overall view
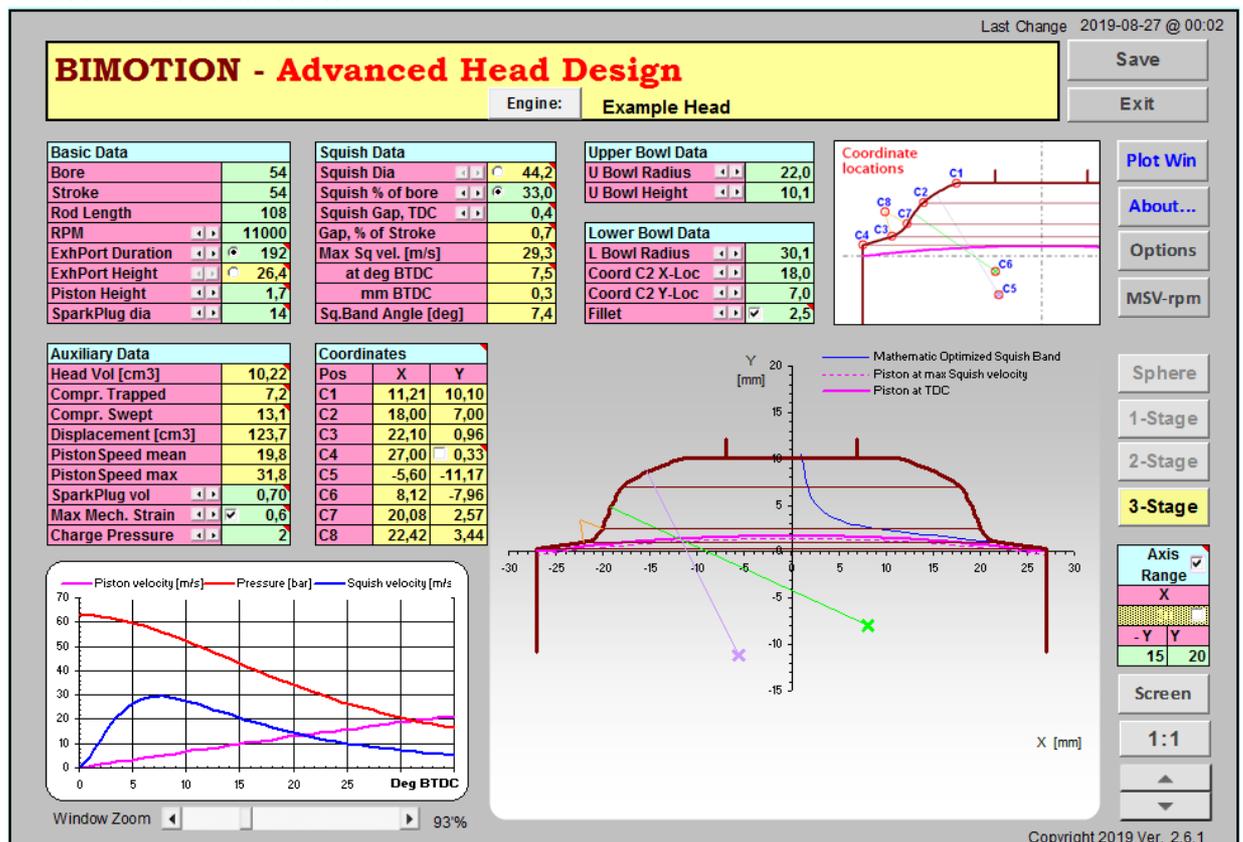
Picture 2. Head Design page.

Green cells are input cells, and yellow are output. All cells except the green ones are locked for changes. The charts and the yellow cells are instantly updated when any green cell is changed. Cells with a red mark in the corner will show a pop up text with recommendations or explanations when the cursor is hovering above them.

Frequently changed cells have small spin buttons for +/- increment change.

The changes becomes more interactive and user friendly with a minimum of keyboard work.

There are two screen modes accessed from the 'Screen' button. One full screen with hidden tool bars, menus etc. for cleanest possible view and one in Excel toolbar window view. When

full screen is enabled, other windows can not be shown at the same time, this is possible in non-full screen window view only.
The other pages can be accessed from the buttons with blue text, and in window mode also from the tabs at the bottom. A fast accessed window zoom scroll bar is found at the bottom .

Picture 3. Page tabs.

Plot: This page contains a plot chart in which the user can select what to plot
About: Information about the author, latest available version, online manual and web link.

3.2   Project Name

The 'Engine' button will open a cell for editing the project name. The Cell will be closed if the text is entered by return key or if a sheet tab is changed.

Picture 4.

3.3   Basic Data

The units are in mm, m/s, cm3, rpm, degrees.

Basic Data	
Bore	54
Stroke	54
Rod Length	108
RPM	8900
ExhPort Duration	190
ExhPort Height	26
Piston Height	2,2
SparkPlug dia	10

Picture 5.
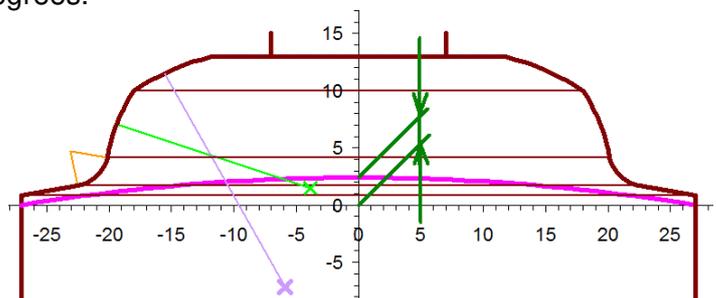
Picture 6. Piston Height.

3.4   Auxiliary Data

Auxiliary Data	
Head Vol [cm3]	11,43
Compr. Trapped	6,6
Compr. Swept	11,8
Displacement [cm3]	123,7
Piston Speed mean	16,0
Piston Speed max	26,0
SparkPlug vol	0,30
Max Mech. Strain	0,5
Charge Pressure	1,5

Picture 7.

This box gathers different design parameters.
Max Mechanical Strain is a very important variable in a race engine, all structure deflections that affects the squish gap is entered in this cell. Crank deflection is usually the most important parameter to investigate. The piston may not at any time clash with head, so this gap must be a minimum value of 0.1mm at max designed rpm. The value is either measured from bench tests at max designed rpm based on experience. A good start is to measure the stock squish gap and reduce it from that distance. One common method to decide the actual strain is to reduce the gap in small steps and carefully listen to any sound change that indicate a piston to head clash at maximum rpm, and then back off one step. The squish velocity can be calculated for each step before testing so detonations are not at risk if a too high squish velocity is reached.

The method of using the strain feature is as follows:

1. Activate the strain cell and set a reasonable strain value for the design rpm , as a norm not less than 1% of the stroke.
2. Design the geometry and set the squish gap to achieve your chosen squish velocity (at design rpm)
3. Click the MSV-rpm button and check how the strain is increased with rpm above the design rpm (over-rev margin). You will also see how the squish velocity performs below the design rpm.
4. Change your design untill the squish velocity is acceptable over the designed rpm range. If the MSV-rpm button becomes red then it means that there is a clash between the piston and the head at the last rpm value in the chart.

| MSV-rpm |

Elastic Strain Dependency
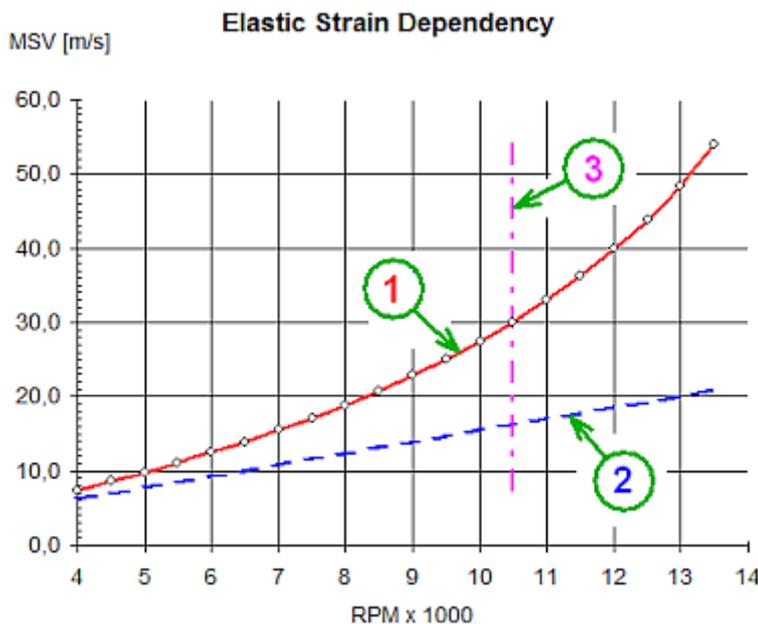
1) The distributed effect of a decreasing squish gap under influence of a given crank bending strain at tuned RPM.

2) Reference curve with no strain for comparison.

3) The tuned RPM for peak power.

Picture 8a. Chart of MSV-rpm-strain dependence

The strain dependent squish gap parameter is very sensitive to max squish velocity, which means that the squish gap conditions vill vary with the rpm. By swaping the check box on/off, this effect can easily be investigated. Finally uncheck the box to set the strain to zero, this provides the manufacturing dimensions (strain=0 at 0 rpm).

The Charge Pressure applies to the exhaust pipe back pressure cylinder charge just before exhaust port closure. The recommended pressure range shows how the peak compression pressure is affected, it does not affect the squish behavior.

3.5   Squish Data

Squish Data		
Squish Dia	◀ ▶ ⊙	39,6
Squish % of bore	○	46,2
Squish Gap, TDC	◀ ▶	1,2
Gap, % of Stroke		2,2
Max Sq vel. [m/s]		19,6
at deg BTDC		9,5
mm BTDC		0,5
Sq.Band Angle [deg]		9,83

The Squish dia is located at the squish gap, defined in picture 14. The variation of the squish velocity versus crank degrees is shown in a separate diagram. The maximum squish velocity is reached just before TDC. 'Squish % of bore' applies to the flat area ratio.
Either of these variables can be entered by toggle the option button. The gap as % of stroke can be informative for comparison between different engine sizes.

Picture 8b.

5

3.6 Coordinates

Coordinates		
Pos	X	Y
C1	10,922	10,100
C2	16,000	8,100
C3	22,100	0,962
C4	27,000	0,327
C5	-5,461	-11,211
C6	6,505	-7,712
C7	18,575	3,578
C8	22,679	5,425

Picture 9a.
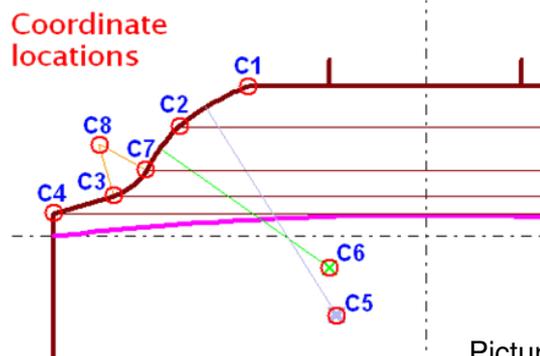
Picture 9b.
Picture 10. Coordinate locations C1 – C8.

The coordinate table is used for manufacturing. The coordinate locations picture and table is changing with the different head types. The cell C4Y has a checkbox for custom user input. Enabling it will turn the cell green and available for changing the squish band angle by altering the coordinate. A very flexible feature! Note that the 3'rd decimals are for technical CNC modelling compatibility purpose only, it has no relevance to manufacturing or MSV calculation.

3.7 Split Line

Coordinates relative split line		
Pos	X	Y
C1	10,922	8,600
C2	16,000	6,600
C3	22,100	-0,538
C4	27,000	-1,173
C5	-5,461	-12,711
C6	6,505	-9,212
C7	18,575	2,078
C8	22,679	3,925

Picture 10a.

The combustion chamber is in the Head_Design page modeled with the piston in Top Dead Center (TDC) to be the reference for the coordinates. Mostly, there is a deck height from TDC to the Head split line, and a gasket in between. From the Option button and then Split Line button, a dialogue window can be used to recalculate the coordinates for any distance to the TDC for

easier manufacturing and measurements, including negative values when TDC is above the split. The minus sign (-) can be inserted before the value in a second step or typed after as "1,5-". The interactive calculation method require this order of input.

The dialogue can not be printed unfortunately so it is recommended to use the keyboard's 'Print Screen' key to copy the window screen and paste it into a picture viewer and print the picture.

Picture 10b.

3.8 Upper Bowl Data

3-Stage

Upper Bowl Data		
U Bowl Radius	◀ ▶	11,0
U Bowl Height	◀ ▶	9,0

Picture 11a.

The upper bowl radius is located between C1 and C2.
The upper bowl height is defined as the Y-coordinate of C1.

2-Stage, 1-Stage, Sphere

Bowl Data		
Bowl Height	◀ ▶	9,0

Picture 11b.

With single bowl, the table input is reduced.

6

Dependent on head type, the program shows warnings about faulty or impossible geometries. The Coordinate location picture shows the definition and a red cell becomes red to show where the problem is (see picture 11c). This typically happens with positive edges or non-conecting curves from small radiuses. In most cases the relevant cells that can be canged to solve the problem are turned into red.

Upper Bowl Data		
U Bowl Radius	◄ ►	11,0
U Bowl Height	◄ ►	4,0

Picture 11c.

3.9   Lower Bowl Data

3-Stage

Lower Bowl Data		
L Bowl Radius	◄ ►	29,8
Coord C2 X-Loc	◄ ►	19,3
Coord C2 Y-Loc	◄ ►	5,9
Fillet	◄ ► ☑	6,0

The lower bowl radius is located between C2 and C3. (See picture 9b).

Picture 12a.

2-Stage

Bowl Data		
Bowl Radius	◄ ►	17,4
Coord C2 X-Loc	◄ ►	19,3
Fillet	◄ ► ☑	6,0

With 2-stage, the non-relevant y-location parameter is dimmed. As the head type gets simpler, more parameters are reduced.

Picture 12b.

1-Stage

Bowl Data		
Bowl Radius	◄ ►	23,2
Fillet	◄ ► ☑	6,0

Picture 12c.

Bowl Data		
Bowl Radius		29,8
Fillet	◄ ► ☑	6,0

Picture 12d.

4   SQUISH BAND

4.1   Mechanisms

The mechanism of a squish band is to increase the vaporizing of the fuel and add kinetic energy which increases burn efficiency. Also, a correct designed squish actually reduces the detonation risk. The reason is that as the gas is compressed, the heat is increased to a temperature 4-5 times the metal, and the locally high squish velocity increases the convection coefficient for heat transfer. The end zone gas is cooled off by the surrounding metal to a point where detonation can be avoided, even under high bmep and high compression ratio conditions.

However, a too large squish action will increase the end zone gas pressure and heat to a level where detonation will occur. Usually, a squish velocity of 25-50 m/s is the upper limit dependent on design, materials, cooling, fuel, etc. It also consumes energy. The fuel usually burns at 30-50 m/s and it will serve as a good limit for the squish velocity. A typical value for a motocross engine ar the design rpm is 28m/s as an example. Note that the squish velocity is sensitive to e.g. crank bending (strain effects) since the squish gap is reduced as the rpm goes up and loaded material is stretched. (See the Strain section below). For high performance racing engines, the design of squish action must be carried out by a judicious combination of theory and experimentation.

Squish action and exhaust pipe charge increases with rpm and consequently burn rate, which is the reason why the ignition timing needs to be reduced in a 2-stroke engine in contrary to a 4-stroke. The Charge Pressure parameter in the program shows how the compression pressure is affected. The exhaust pipe charge pressure for an engine with bmep >8 bar varies from 0 at mid range rpm to 2 bar (atm.) at peak power. High peak pressure increases the power if the fuel heat release timing is correct (burn rate), but also increases the mechanical noise. Noise also increases with increased squish. Detonation is an explosive behavior with reaction velocities in the region of 6000 m/s and bad designed squish bands will cause such detonations which destroy the surrounding metal and sometimes hammer the piston, making it expand by plastic deformation over a big area and seize.

4.2   Geometry

When the gas at the squish band is moving into the center in picture 13, it have to increase its velocity due to the fact that the area is decreasing. The red length is shorter than the blue length in the picture and the gas must pass the red line as it is squished.

To optimize the squish behavior there have to be a constant squish velocity over the squish band.
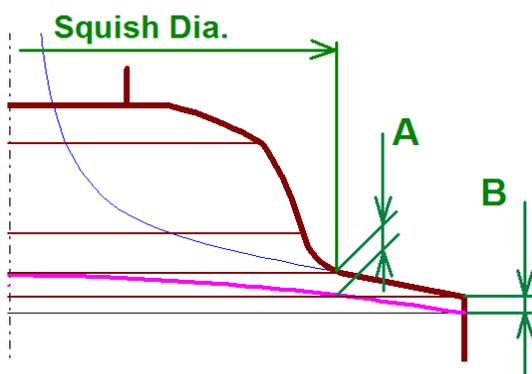
Picture 14. Definitions.
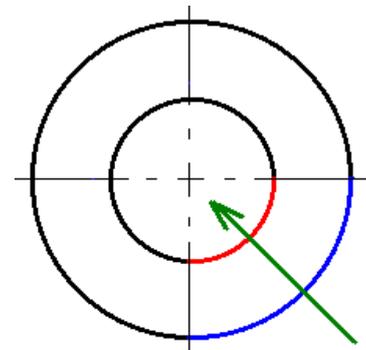
Picture 13. Head projection

This is achieved by tapering the squish band height with the corresponding area ratio, so that **A** is the **Squish Gap** and **B** is the reduced height found as Y(C4) in the coordinate table of the program. This height reduction also reduces the inefficient burned volume. The blue line shows the mathematical correct squish band shape.

We can see that a strait line will approximate the shape perfect over the squish band width. The squish taper angle is not constant; it increases with increased squish gap **A**. The taper angle is tangent with the piston edge at **B**. Usually the head is mounted with a gasket to the cylinder. The gasket height is then included in the dimension **B**.

The Squish diameter definition is decided from where the maximum squish velocity is located. The squish band is designed to have a constant velocity when cell C4Y is set to automatic (and maximum over the whole band). At the point where the fillet radius starts (at location **A**), the squish velocity will slow down due to the area (volume in 3D) increase. Since the actual head design parameter is max velocity, the indirect design parameter must be the diameter that affects this velocity.

The squish velocity, piston velocity and cylinder pressure is shown in a separate chart. The exhaust pipe charge pressure only has an impact on the cylinder pressure.

Note how the squish velocity increases to a certain point although the piston speed decreases.
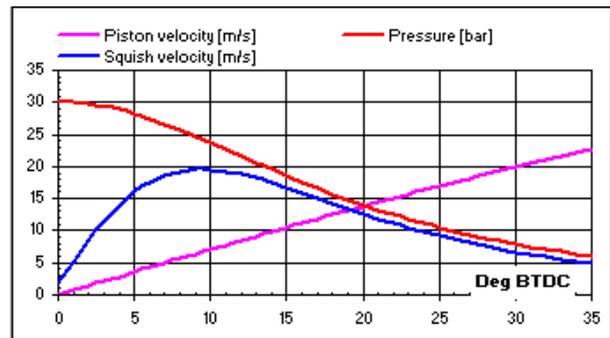
Picture 15.

5   BOWLES

5.1   Alternative geometries

The Bimotion Head can be designed with different geometry types.

The different geometries are selected with the buttons in picture 16.

Hemi-sphere: The radius origin located on the vertical axis (x = 0).

1-stage: The radius is displaced from the vertical axis (x ≠ 0), the bowl upper edge is horizontal aligned with the spark plug hole.

2-stage: x ≠ 0, The bowl upper edge is not aligned with the spark plug hole, this results in a flat roof.

Picture 16.

3-stage: An extra bowl is added. The shape is mainly controlled by moving the control point C2 (picture 9b) and the roof height.

17 a) Sphere

17 b) 1-Stage

A = Squish Diameter
B = Squish Gap
C = Upper Bowl Radius
D = Upper Bowl Height
E = Lower Bowl Radius
F = Coord C2 X-Location
G = Coord C2 Y-Location
H = Spark Plug Diameter
I = Bowl - Squish Band Radius (Fillet)
J = Piston Radius
K = Squish Band Angle
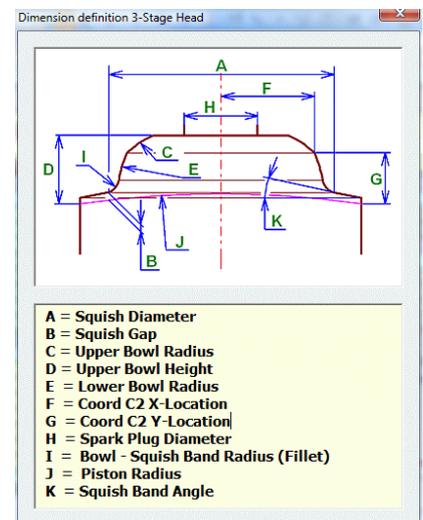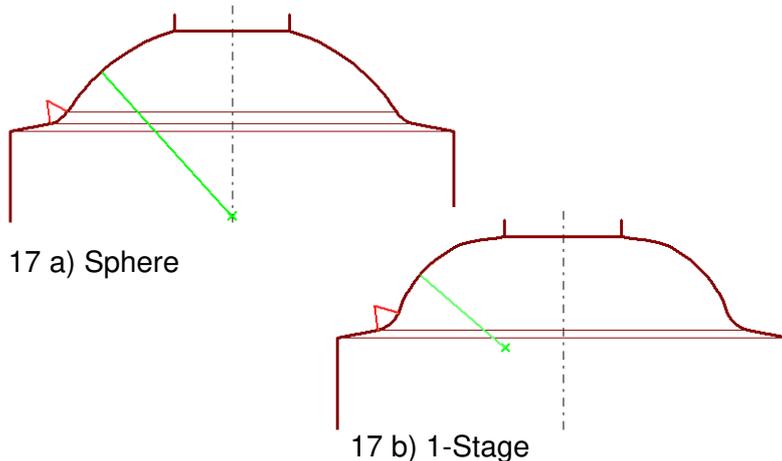
Picture 17 e) Definition

17 c) 2-stage

17 d) 3-stage
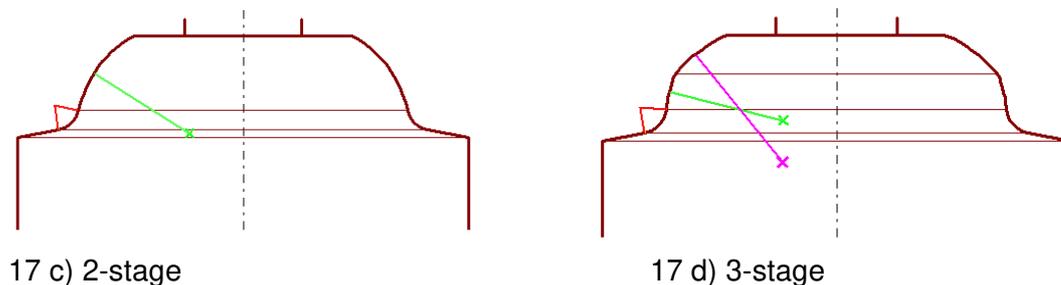
Almost any parameters can be given as long as the entered dimensions are valid to align the curves. Note that the calculation is made instantly as a value is entered which means that you need to careful not to enter erroneous numbers or non-numeric characers by misstake.
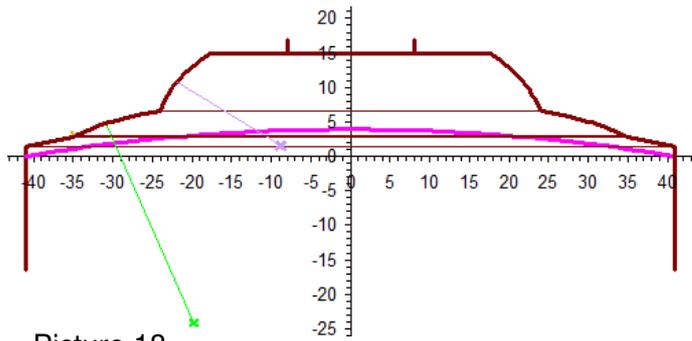
Picture 18.

6   CUSTOM CHART

The chart is customized by changing the axis range in the green cells (X,-Y, Y) or adjusting the plot area height with the arrow buttons. The upper checkbox (at "Axis Range") hides/unhides the axis tick values/marks in the chart and replaces the solid axis line by a dot-dashed line for better visability. The lower check box swaps between automatic and manual chart x-axis max/min value adjustment.
The 1:1 button will adjust the axis aspect ratio by reducing the plot area height. If any of the green cells change to red after the 1:1 adjustment then the axis range have to be adjusted too in order to plot the correct size.
If any cell interior becomes red, then the 1:1 scaling was not possible with chosen values.
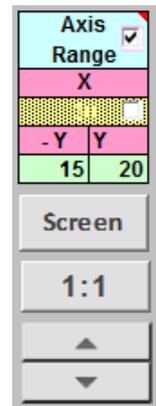
Picture 19

7   PLOT

The plot sheet allows the user to scale the plot to the printer by the Chart Scale variable. If the length/height ratio isn't perfect on screen then change the window zoom slightly, the ratio isn't floating perfect with Excel's window zoom. However, even when the length/height ratio is correct on the screen, Excel does not export the correct length/height ratio to printers so an additional ratio adjustment has been added. Measurement on a print out is recommended with 'Grid Major' activated for verification. The "Lock Chart Scale" button locks the chart for changes so accidental changes will not be done once the printer scales have been set.

Picture 20

8 PRINT / OUTPUT

The active page is printed by using the print button (found in the options dialogue form in the Head Design page and in the Plot page). A gif picture is saved to a location you will choose from a "Save to Folder" dialogue. After clicking OK, a dialogue form is shown in 3 seconds to notify the name of the chosen folder. The yellow button will open that folder.
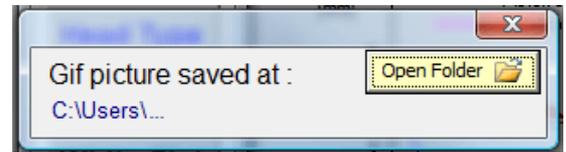
Picture 21

The coordinate data can be exported into either a text file or an Excel file to support for CNC manufacturing input. The button 'Export Coordinates' is found in the 'Options' window. Choose text or Excel as the default output format in the 'About…' page. (See picture 23). The coordinates are calculated with the Split Linte distance included and the file is saved in the same folder as the program runs from.

Picture 22

9 ABOUT…

The program is automatically checking for new versions. You can request for free updates during the first 4 years after purchase. After that period you may order a maintenance service period of another 4 years for a fee. The 'Request update' button will open your default mail program with a texted request.

The program can import translation files in some languages, the which ones that are availabe for download on the bimotion site. The translation file is imported by clicking 'Read language file'.

Three viewing settings are available with checkboxes and a data export setting (see Print/Output above).

and
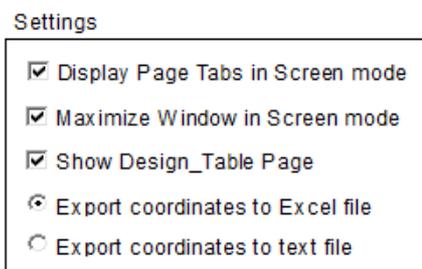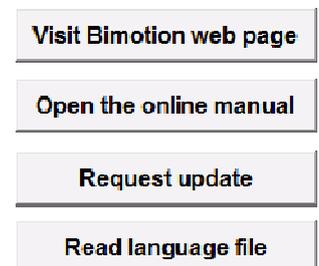
Picture 23

Picture 24

Checking the 'Show Design_Table Page' checkbox will add a thumbnail tab with a design table page, which is a special option for CAD-model input parameter synchronisation.

Besides the input design parameters in that table, there is also a cell in the R-column with the head's "Flat Plate Volume" that can be used for manufacturing check. The volume is the combustion volume + the piston dome volume, i.e. something that can be measured in the head standalone.
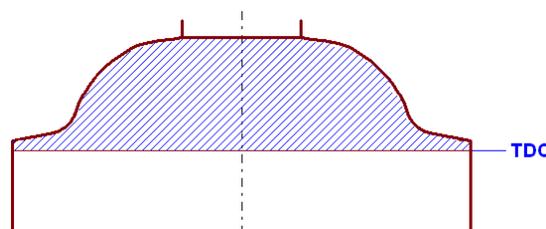
Picture 25

Picture 26

If a split line value is used in in the Options choice (see 2.7) then the volume is reduced to the red hatched area, i.e. the true manufactured flat plate volume.
In this example, the head volume is calculated 0.5 mm above TDC.

The Flat Plate Volume value is calculated when the 'Split Line' window is closed.

Split Line

Distance from piston TDC to head split line. Type any minus sign after the value input , e.g 1.5- or 1.5 first, then add -

Use 'Print Screen' to Print

0,5

Coordinates relative split line		
Pos	X	Y
C1	9,538	11,500
C2	18,000	7,600
C3	22,100	1,030
C4	27,000	0,073
C5	-4,769	-9,977
C6	6,524	-4,852
C7	19,804	3,106
C8	22,675	3,974
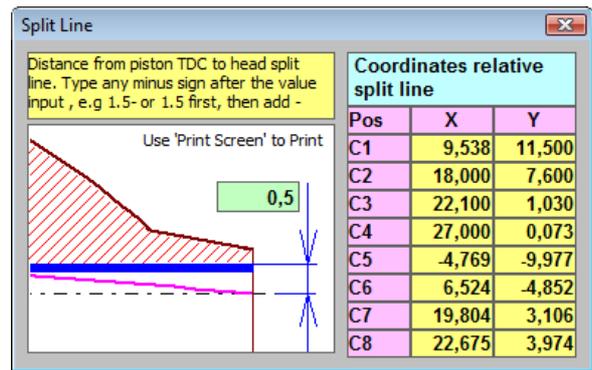
10 DESIGN STRATEGY

Picture 27

10.1 Prerequisites
When a head is designed, some simple properties need to be known.

How is the engine used ?
How many gears?
What tuning degree should it be designed for?
What is the cooling capacity?

These things decide how to design the squish band. A fixed geared gokart will be driven with wide open throttle (WOT) at low rpm out of the corners. That requires wide sq. bands (over 50%) since the head will be cooled down. The fuel mixture will not be very well atomized but condensed in the head. A wide sq. band will increase atomization and burn ratio at low and midrange rpm. A wide sq. band also consumes energy (hp).
On the contrary, a road racing engine will need less sq band, at the maximum 50% since it runs very hot and conserves the energy in the head better.
The absolute compression pressure is not only decided by the ratio but also by the exhaust pipe. A high rpm race engine charge the cylinder with about 2 bar (atm.) from the pipe, so a low compression ratio is needed to get it right at the tuned rpm. Usually, a moving exhaust valve is used to increase low rpm compression ratio. With a non-efficient race pipe, more compression ratio can be used. *The head design is by other words also dependent on pipe & port design as well.* In general, the compression should be as high as possible for high power engines for maximum burn efficiency. If fuel consumption is regarded and the engine is driven at low rpm quite often, a lower compression ratio should be used for best economic efficiency. Compressing air is energy consuming.

10.2 Replication
When a cylinder head is modified, it needs to be modeled in the program by using all the green cell parameters, including the squish gap distance. This distance must be measured when the head is mounted to the engine, preferrably by using clay, solder tin or equal to be squished between the head and piston, among the other geometrical parameters stated. Estimate or add at least 1% of the stroke from crank bending deflection at maximum rpm to use in the program with the strain check box enabled. (Professional tuners evaluates this strain by full rpm load bench testing in order decide a safe minimum squish gap to avoid a piston-head clash at maximum over-rev).
That will give you the existing performance of sq. velocity at max rpm and compression ratio to evaluate before the modification. The rpm chart will distribute the crank strain and show how the sq. velocity is affected by the decreasing sq. gap when the rpm is increasing. (The strain is increasing from 0 mm at 0 rpm to your stated strain at your stated rpm). When your design is ready for manufacturing, then the strain check box should be unchecked to show the parameters at 0 rpm.

11 TROUBLE SHOOTING

Q: "I get a runtime error when I click a button or change a cell" or
" The buttons do not respond"
A: You probably need to change your security settings in excel.

Do this in Excel 2003 :
1) Open the excel sheet www.bimotion.se/Pipe/ResetMenus.xls .
(Click the link here and open the file, this will reset your menus in Excel)
2) On the Tools menu, click Macro and Security...
3) Set the security level to Low
Open the Bimotion program again and check the
result, this should cure the problem.
You were probably not allowed to run the necessary
macros before. (See pictures below).
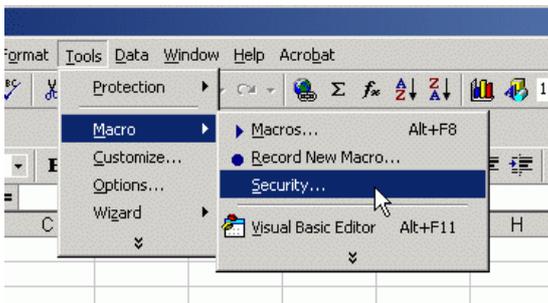
In Excel 2007 and later, enable the setting:
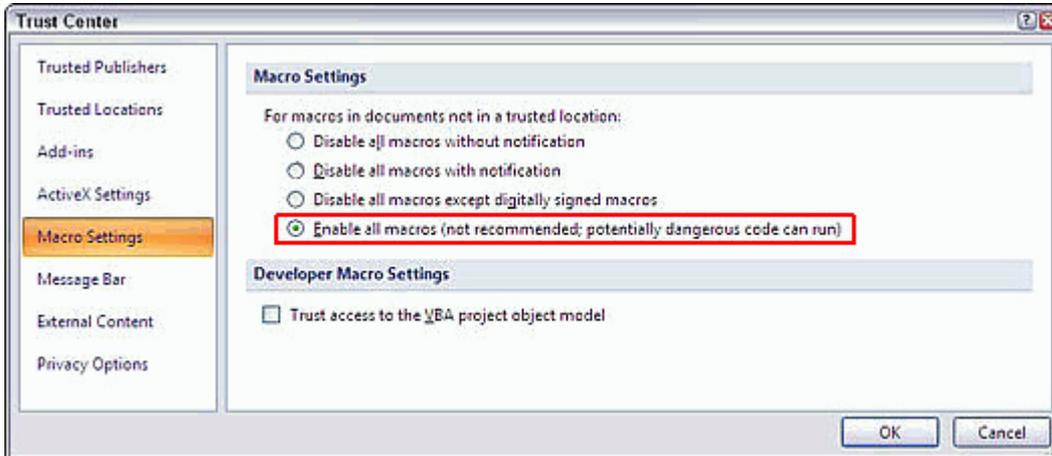
and/or the downloaded xls-file might need to be "unblocked" in order to run the program code.

When Excel introduced the xlsx and xlsm file format, a
block was also introduced for running VBA macro code in
the older .xls file format like this file has (in order to
maximize compability for all Bimotion users).
(xlsm = macro activated file).
In later Excel versions you need to manually unblock the
security restriction in downloaded xls-files in order to run
macro code, which the buttons in the program are using in
order to excute the functionality.
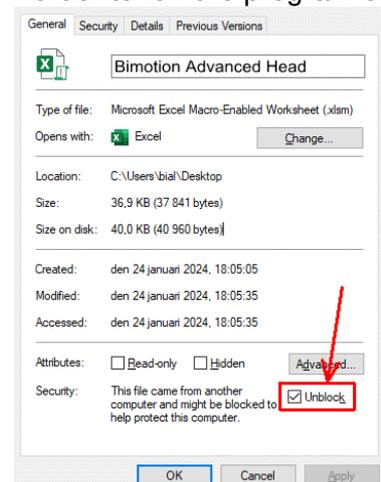
Do this:
- Right click the Bimotion Excel file and chose "Properties"
- In the General tab click the check box "Unblock"
- OK

If you cannot find the "Unblock" checkbox, then the file is not blocked.

Q: "I cannot input decimals, and when I do, strange things happens."

A : Always use decimal separators according to your Windows regional settings.
If you get errors with dot (.) then use comma (,) etc.
Comma is used as decimal identifier in most countries, but there are exceptions.

Q: In the "About…" page, "Latest available version" says "No internet connection"

A: If there is an internet connection and the message "No internet connection" is shown, then it might be an internal Excel conflict if you use Excel add-ins. If you use add-ins, close Excel and restart in "Safe Mode" by holding the Ctrl key down while starting Excel. Choose Safe Mode as start option in the appearing dialogue. This will disable add-ins and avoid such conflict.

Q: "When I go from 3-Stage to Sphere dome it errors out. I see hashtags in all of the compression ratio and squish velocity outputs.

A: When you are in the sphere geometry and change the only parameter left (Bowl Height), there is a looping numerical calculation done to find the Bowl Radius. As can be seen, it needs some thinking. If/when you make a larger geometry change, like going from 3-stage directly to sphere, the heavy looping sometimes seems to make the internal routine overloaded. To "help" the program and avoid an error, make this kind of change in steps. Click 2-Stage, 1-Stage, Sphere, or at least the 1-Stage change before the Sphere.

Q: "I changed the Bore (or Stroke) and it all locks up with an error message."

A: The program does not check every possible invalid or non logic input, so if the Bore is smaller than the squish band diameter, stroke longer than the rod length, bowl radius too small to connect with the geometry, etc then errors may stop the program.
In that case, make the change in some steps and adjust other parameters to follow the boundary geometry.