Hot Stage Microscopy Analysis Tool

Irving Cruz, Eduard Vergés, Dolors Ayala

1 Input

A collection of more than 200 grayscale images per dataset (2048x1536 16-bit TIFF files). Each collection depicting the evolution over time of the melting in an oven of a basalt sample. See Figure 1a) for a example.

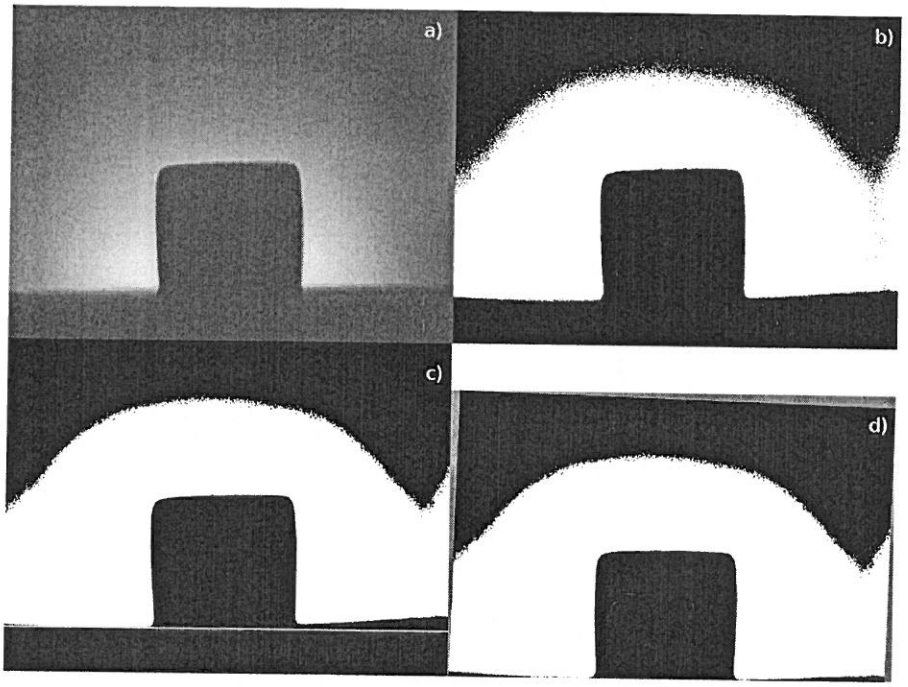


Figure 1: a)Captured image, b)After binary threshold filter c)After noise reduction (Observe that the image is not aligned) d) After aligment operation

2 Preprocessing

In order to obtain the desired measurements, the image needs to be preprocessed. This preprocessing basically consist of a binary threshold filter, a noise reduction filter and an alignment operation.

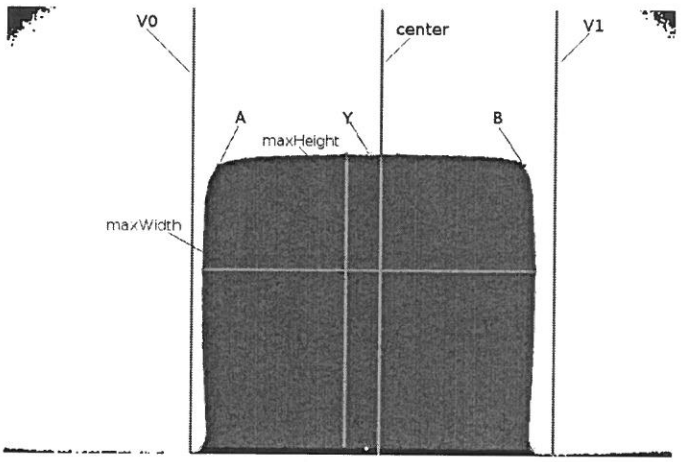


Figure 2: Segmentation and distinctive points

2.1 Binary threshold filter

This filter reduce the gray scale image to a B&W one. We calculate the threshold value in run time , taking into acount the minimum gray value. See Figure 1b)

2.2 Noise reduction

The last filter can generate salt and pepper noise, therefore we apply a noise reduction filter. See Figure 1c)

2.3 Aligment operation

Images can be not horizontally aligned, finding the closest columns in the rigth half and in the left half with more white pixels, we can calculate the correct values to rotate the image and to clip the floor. See Figure 1d)

3 Segmentation and Distintive Points

The segmentation separates the real sample from the background. In order to do this we need first to detect some *distintive data* (see section 3.1) and then we can apply a flood fill algorithm to get an image like Figure 2.

3.1 Distinctive data

The *distinctive data* are a set of data that will help us to calculate the needed parameters to finally obtain the notable points (see Section 4). These points are: (See the Figure 2 for illustration)

center	The center of the image.
V0	Closest column with more white pixels in the left half
V1	Closest column with more white pixels in the rigth half
A	Sample's left-top corner.

B	Sample's right-top corner.
C	Sample's right-bottom corner.
D	Sample's left-bottom corner.
X	Central point between C and D points.
Y	The top from X.
maxWidth	Sample's longest row.
maxHeight	Sample's longest column.

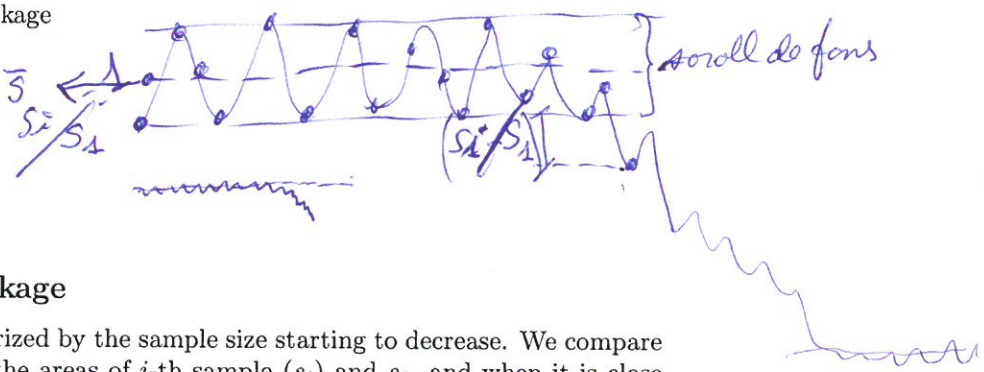
Additional information can be computed from the segmentation like:

- Sample's area.
- Sample's *Axis Aligned Bounding Box* (AABB).
- Lengths of segments between distinctive points.

4 Detecting Notable Points

We have a set S of n images that depicts the evolution over time of the melting in an oven of a basalt sample. $S = \{s_1, s_2, ...s_n\}$ where s_1 and s_n represent the initial and final state of the sample respectively. During this evolution six notable points are detected. These points are:

1. First Shrinkage
2. Maximum Shrinkage
3. Softening
4. Ball
5. Half ball
6. Flow



4.1 First Shrinkage

This point is characterized by the sample size starting to decrease. We compare the relation between the areas of i-th sample (s_i) and s_1, and when it is close to a threshold, say 95% by default, we get the first notable point. Is important to say that the defaults thresholds are editables in our software.

$$\frac{Area_i}{Area_1} \approx thresholds \qquad (1)$$

4.2 Maximum Shrinkage

This point is characterized by the sample size reaching its maximum decrease. We again compare the relation between the areas of s_i and s_1, and when it is close to a threshold, say 85% by default, we get the second notable point.

$$\frac{Area_i}{Area_1} \approx threshold \qquad (2)$$

4.3 Softening

This point is characterized by the disappearance or rounding of the protusions at the corners of the sample (corners and peaks starting to softening). We found 2 ways to obtain this point.

Firts method. When the relation between the areas s_i and its $AABB$ comes close to 1.

$$\frac{Area_i}{Area(AABB_i)} \approx 1 \tag{3}$$

Second method. When the relation between the segment from the right-bottom corner of $AABB$ to point A (or from the left-bottom corner of $AABB$ to point B) and the diagonal length of its $AABB$ is close to a threshold (say 95% by default).

$$\frac{\overline{PA}}{Diagonal(AABB_i)} \approx threshold \tag{4}$$

where P is the right-bottom corner of $AABB$

$$\frac{\overline{QB}}{Diagonal(AABB_i)} \approx threshold$$

where Q is the left-bottom corner of $AABB$

Third method. Using the Freeman Chain Code. If we take the top of the sample, say the first 10% (See Figure 4 a), we can use the Freeman code (using 8 directions) that basically represent the boundary of a binary discrete image. This code is a chain of numbers that represent the relative position of one point of the boundary. The transversal we used is done clockwise and the chain coding scheme is showing in the figure 3.

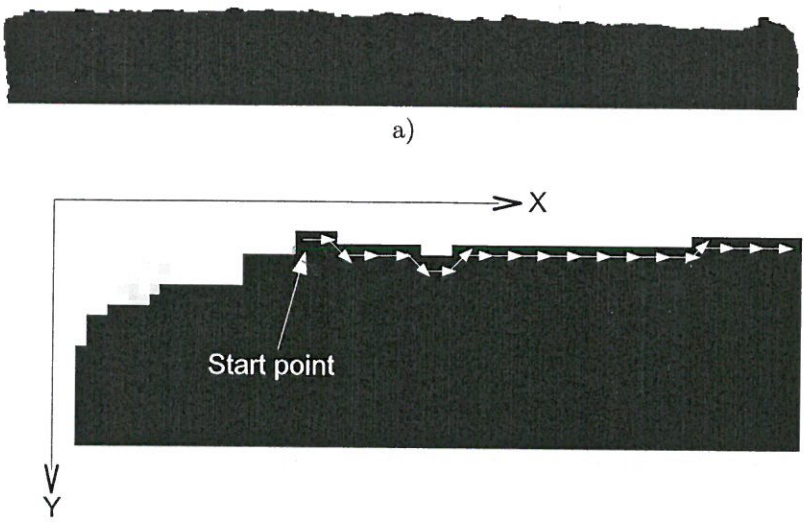
3	4	5
2	X	6
1	0	7

Figure 3: Freeman code scheme with 8 directions

With the Freeman code we are able to calculate the number of occurrences of each directions in the chain, in this way, if the softening is characterized by corners and peaks starting to desapear, we expect that the top of the sample will be as flat as posible, and in the chain code it will be the maximum relation of occurrences of 6-directions over the rest. An example is showin in the Figure 4 b).

$$Maximum(\frac{ChainCode(6)}{ChainCode(All)}) \tag{5}$$

We decide to kept the formulas in 4 and 5 because these detect better the third noteble point.



a)

b)

Figure 4: Example of freeman chaind code. a) The 10% of the sample. b) Zoom and chain code: 6766765666666665666 . . . .

4.4 Ball

This point is characterized by the sample shape being a ball. In order to get the best sample like a ball, we take into account the idea of a circle inside a square, with this, the relation between distances when a segment pass troght the circle and trhougth the square can be calculated.

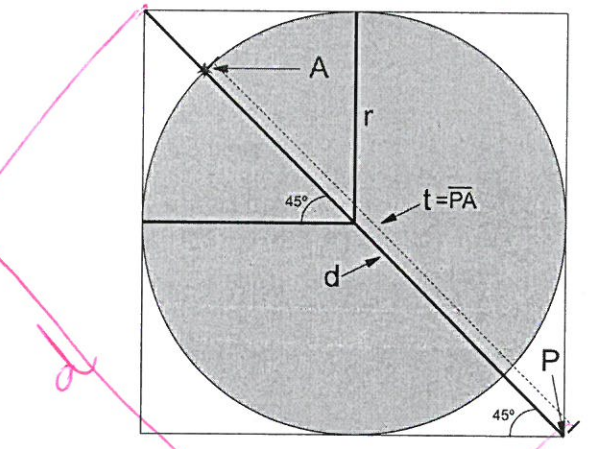


Figure 5: Circle inside a square

From Figure 5 we can get the relation t/d, then

$$t = \frac{d}{2} + r \quad \Rightarrow \quad \frac{t}{d} = \frac{(d+2r)/2}{d} = \frac{1}{2} + \frac{r}{d}$$

$$\text{but} \quad d = \frac{2r}{\cos 45^o} \quad \Rightarrow \quad \frac{t}{d} = \frac{1}{2} + \frac{\cos 45^o}{2} = \frac{1}{2} + \frac{\sqrt{2}}{4} \approx 0.853$$

Thereby, when the relation between the segment from the right-bottom corner of $AABB$ to point A (or from the left-bottom corner of $AABB$ to point B) and the diagonal length of its $AABB$ is close to 85% of size, we get the Ball notable point.

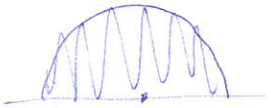
$$\frac{\overline{PA}}{Diagonal(AABB_i)} \approx 0.853 \tag{6}$$

where P is the right-bottom corner of $AABB$

4.5 Half Ball

This point is characterized by the sample shape being a semi-circle. We found 2 ways to obtain this point.

Firts method. If booth s_i's and a semicircle areas are equals. We calculate the semicircle area using the half of s_i's width (or the s_i's height) as the radius.



$$\frac{Area(s_i)}{(\Pi * (maxWidth_i/2)^2)/2} \approx 1 \tag{7}$$

$$\frac{Area(s_i)}{(\Pi * (maxHeight_i)^2)/2} \approx 1$$

Second method. If the width of s_i is the double of its height.

$$\frac{maxWidth_i}{maxHeight_i} \approx 2 \tag{8}$$

We decide to kept the formula 8 because is a simpler calculation.

4.6 Flow

This point is characterized by the sample's height being reduced to approximately $\frac{1}{6}$ of the initial height. We simply compare the relation between the heights of s_i and $s1$, and when it is close to 16.66%, we get the last notable point.

$$\frac{maxHeight_i}{maxHeight_1} \approx 0.1666 \tag{9}$$

5 Example

We have probed our software with many real datasets. Here we show the result for a dataset with 369 images representing the evolution of a basalt sample with 16% of ?. The Figure 6 show the result. The First and Maximum Shrinkage, and the Softening points were detected using the default thresholds. The temperatures are calculated automatically based on temperature ranges provided by the experts.

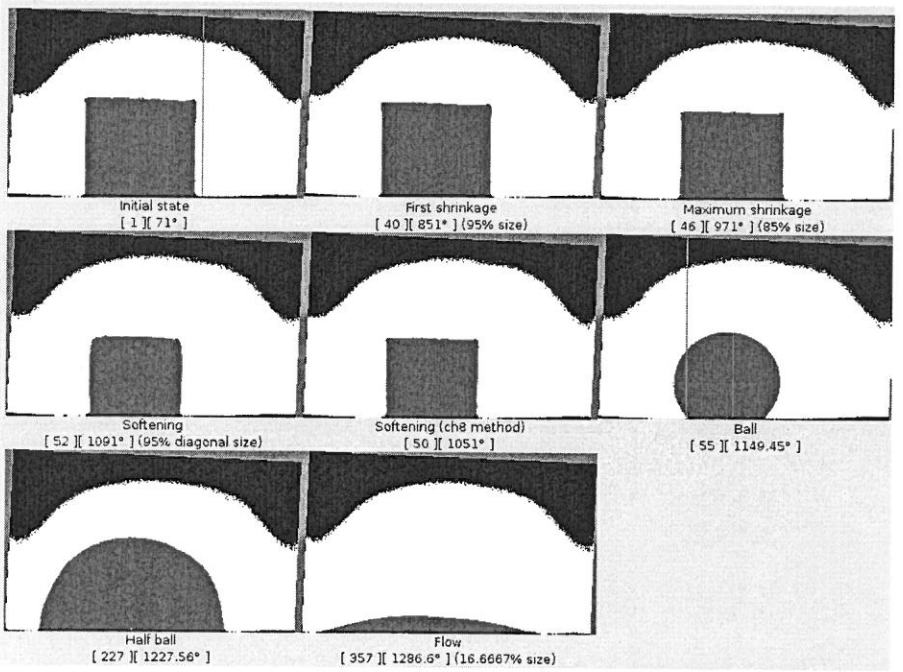
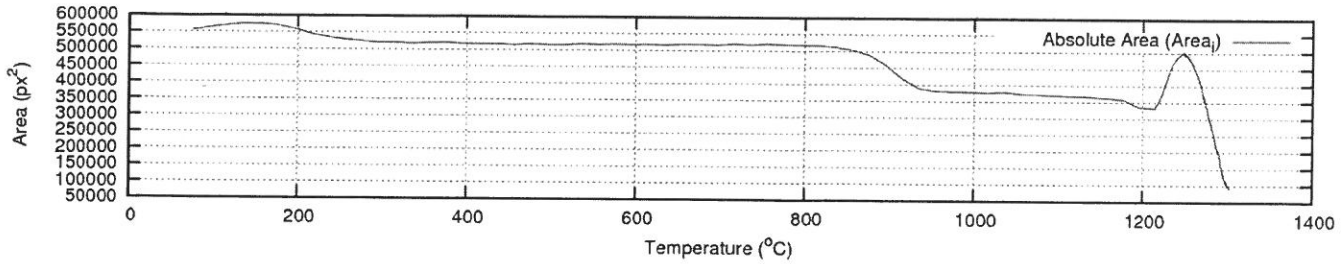
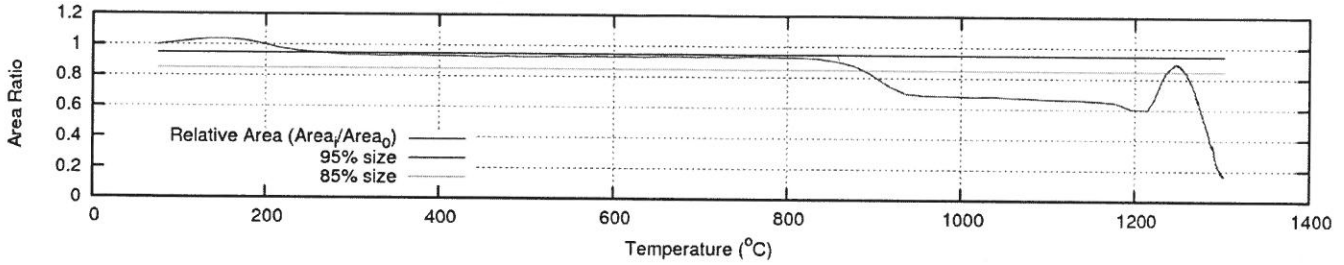
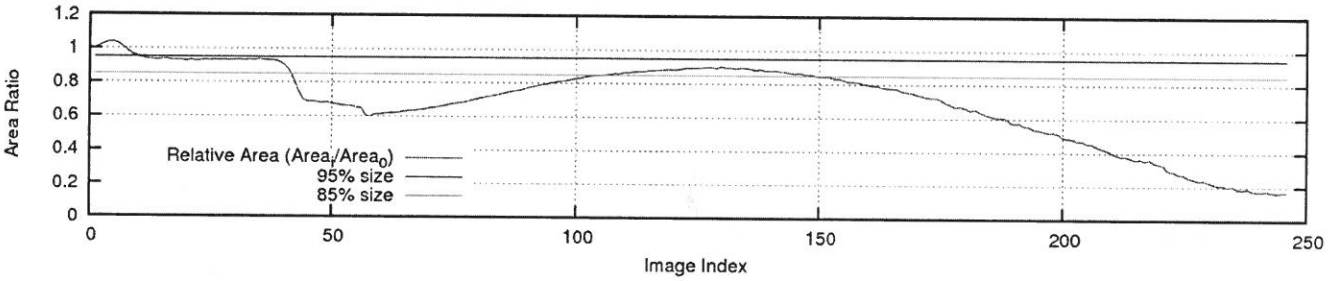


Figure 6: Software result for a real dataset

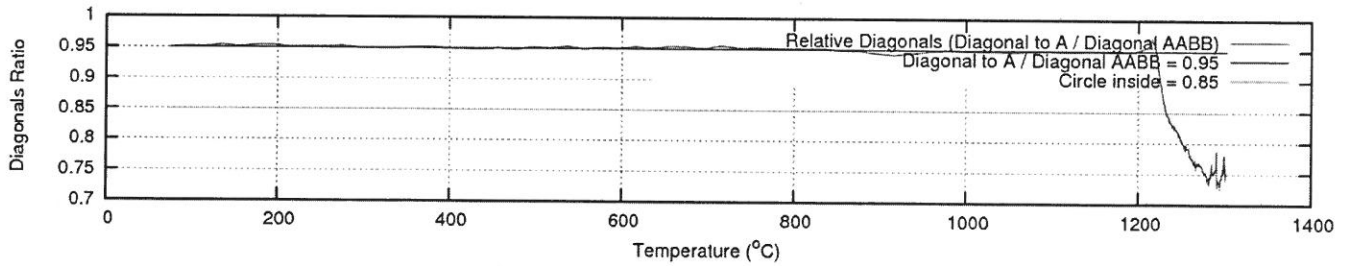
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

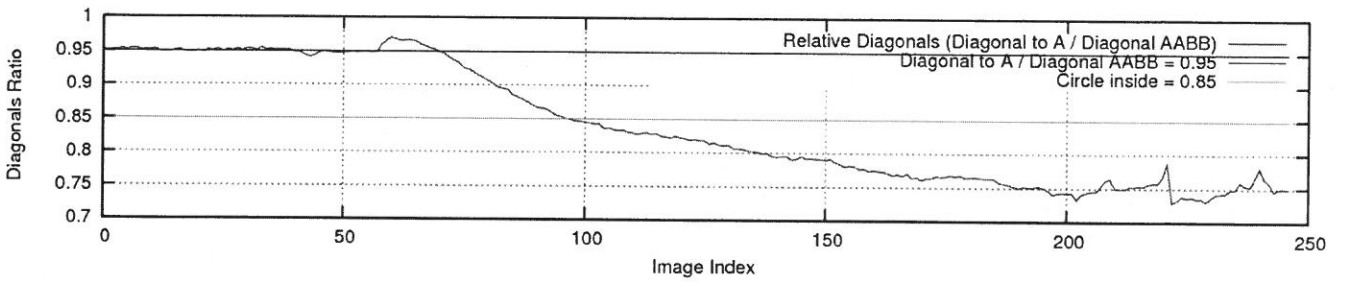


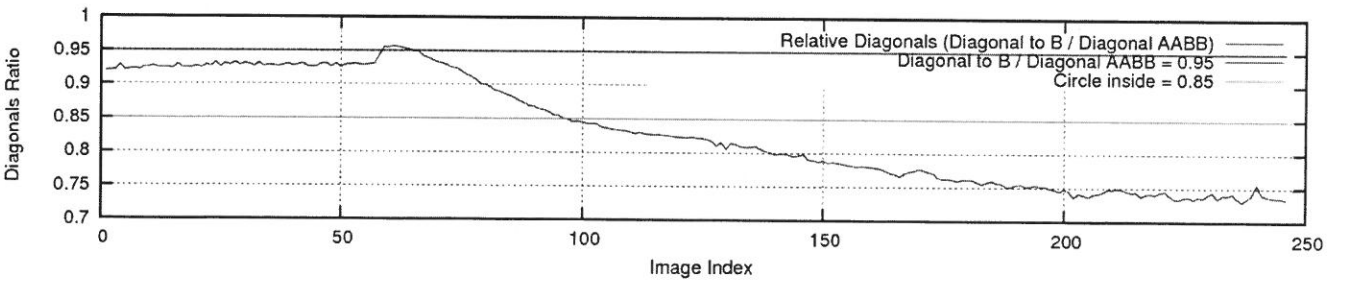




Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball







Dataset: T-0P

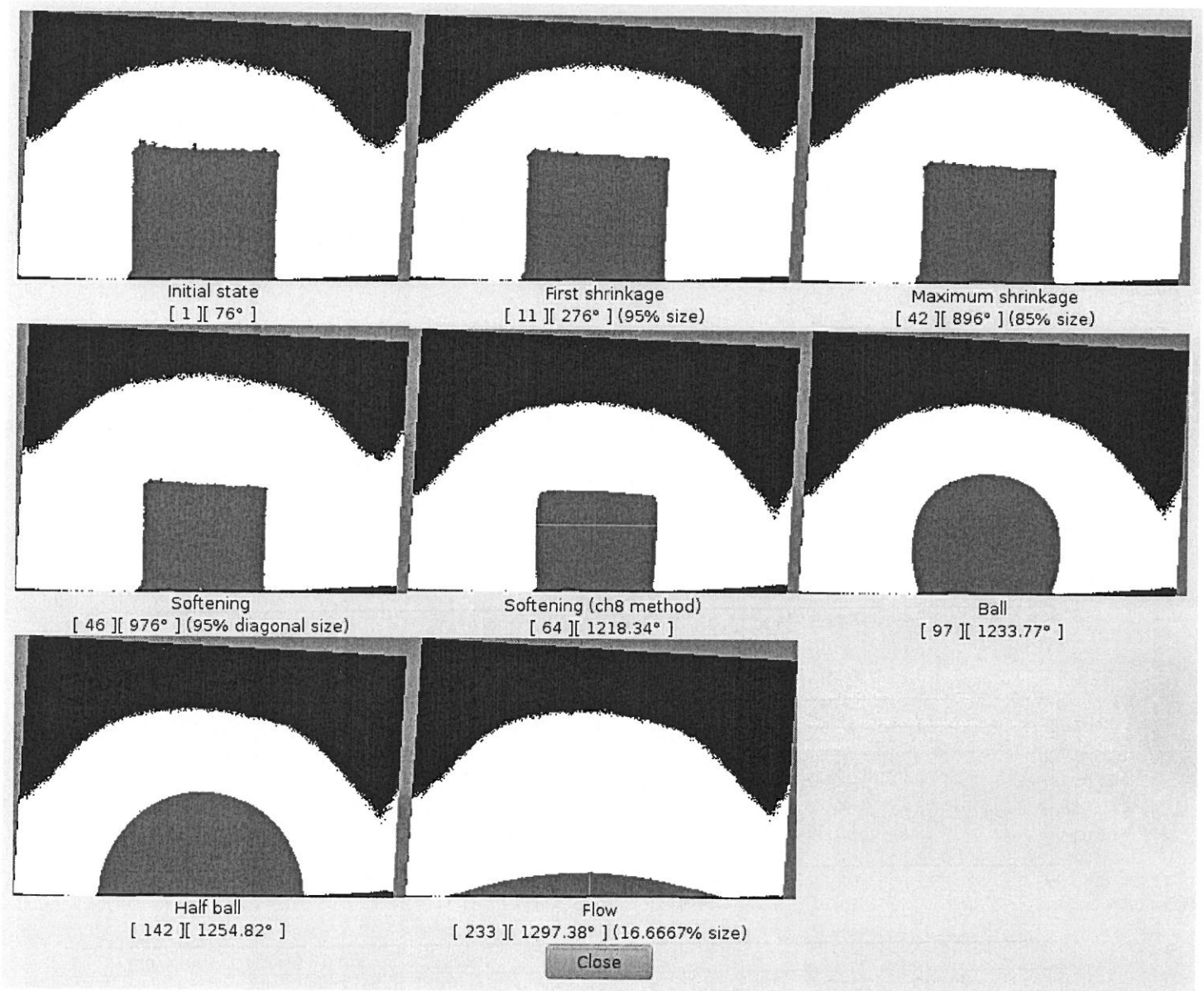
Temperature increment: 10°C/min

Images index	*Temperature*	*Images/min*
1 – 58	70 - 1213	0.5
58 – 246	1213 - 1303	30

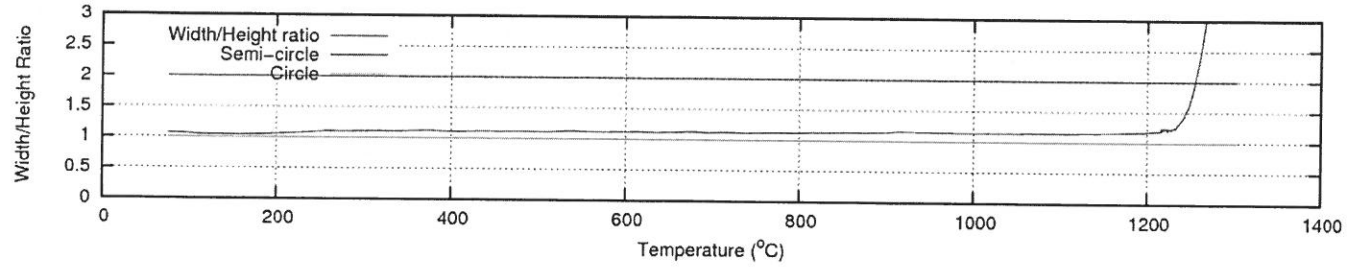
FIXED Table (according to times in Excel sheet)

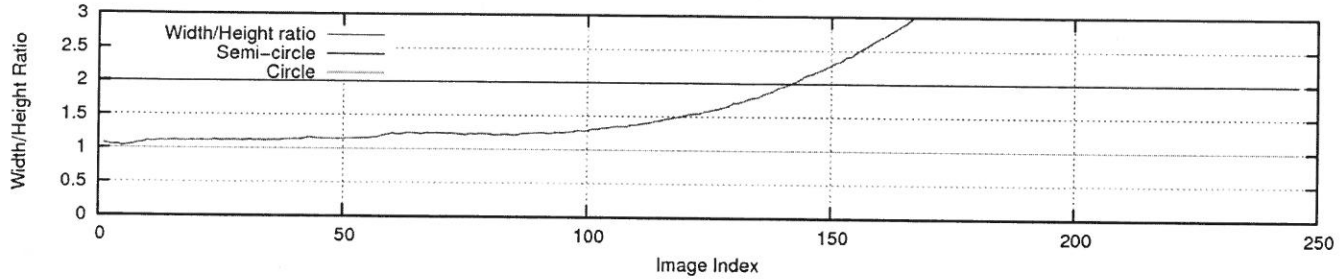
Temperature increment: 10°C/min

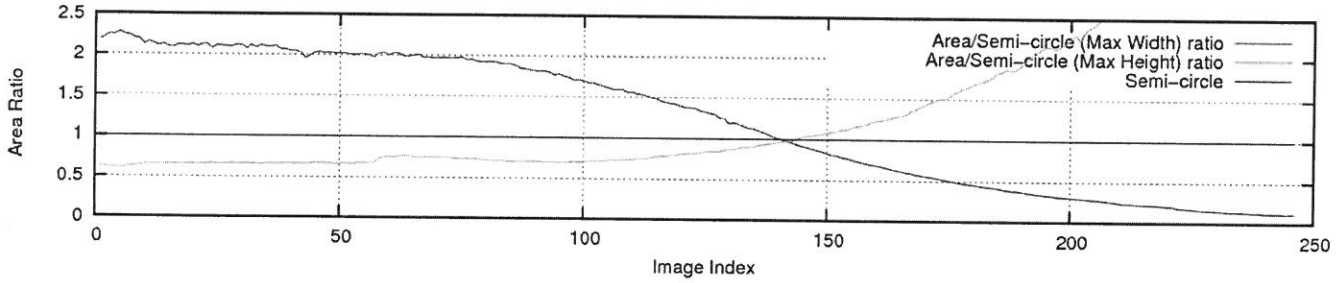
Images index	*Temperature*	*Images/min*
1 – 59	76 - 1216	0.5
59 – 246	1216 - 1303	21.38



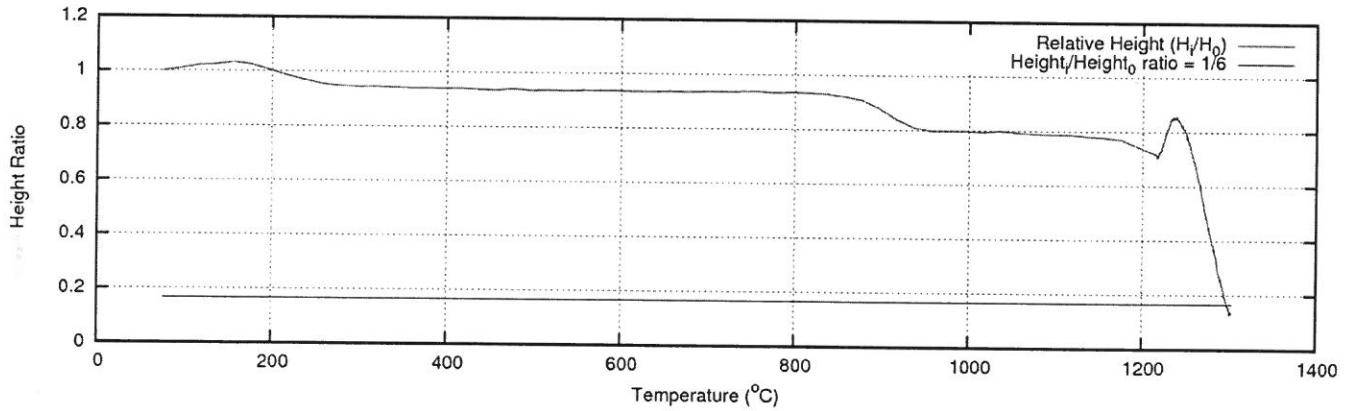
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

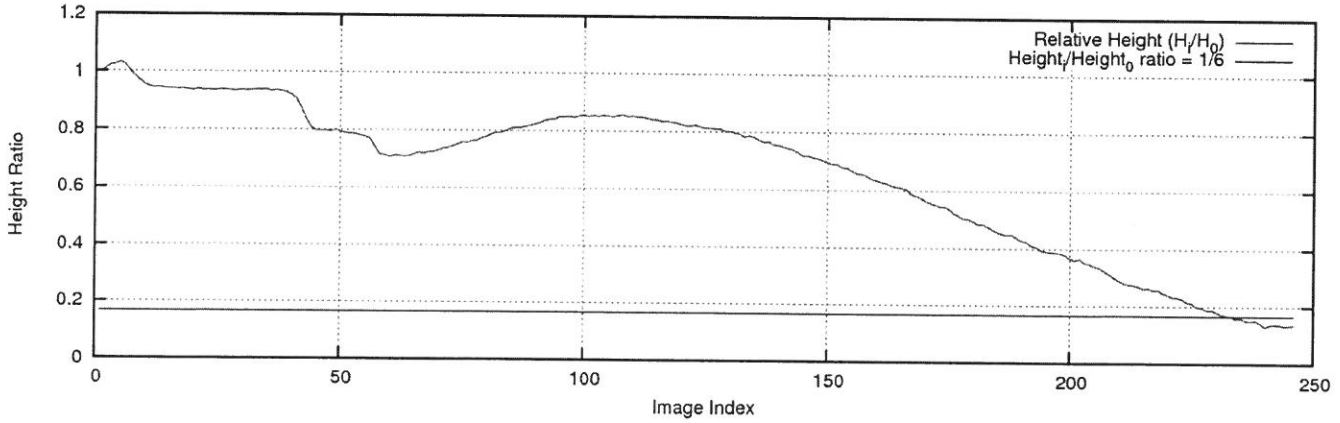




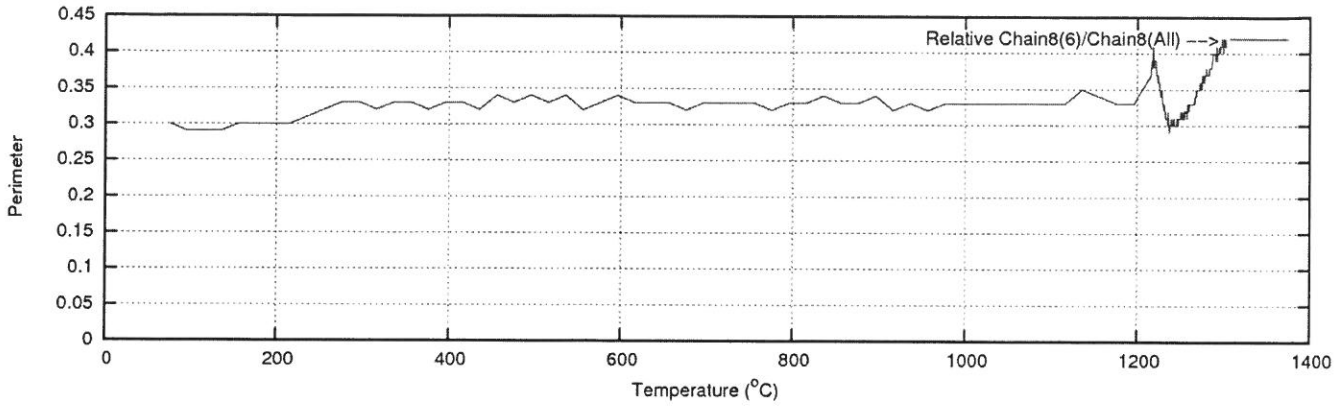


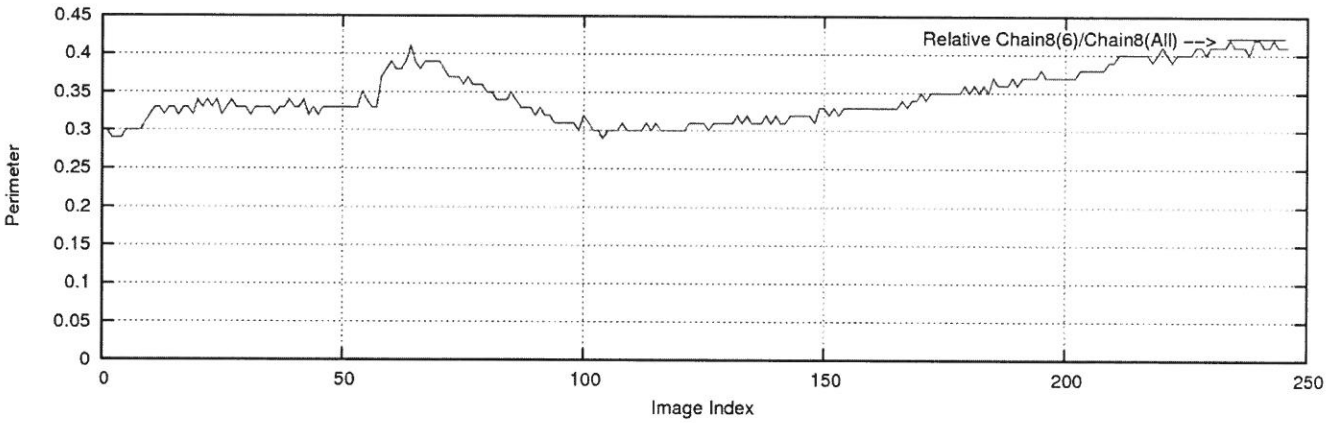
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





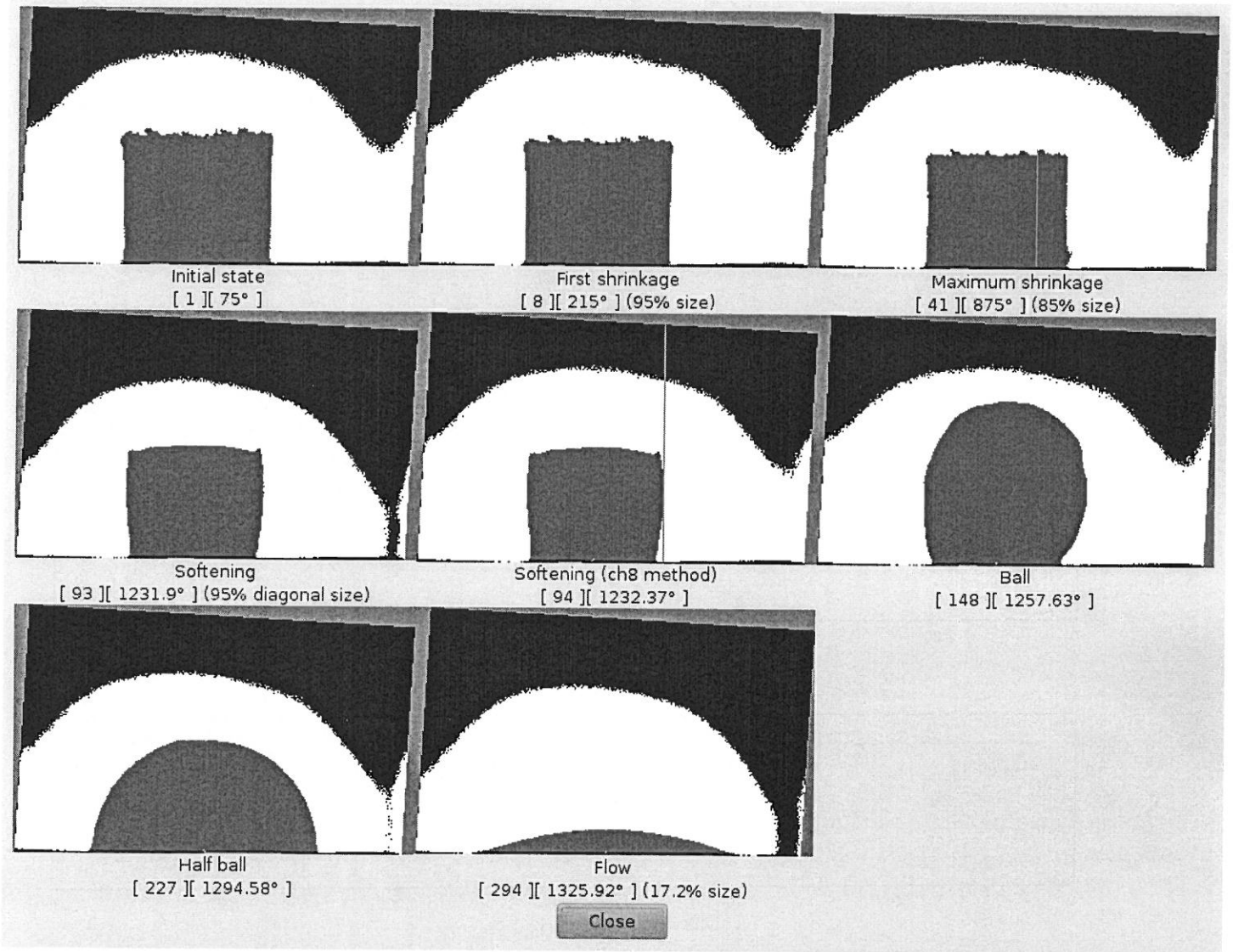
Dataset: T-1P

Temperature increment: 10°C/min

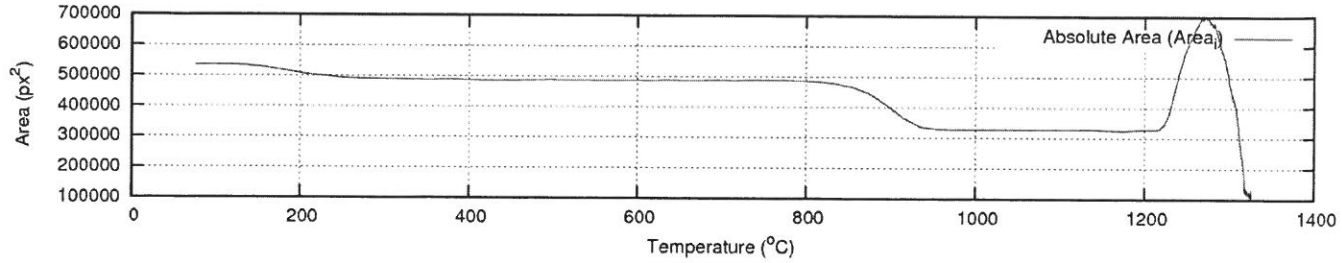
Images index	*Temperature*	*Images/min*
1 – 56	85 - 1190	0.5
56 – 290	1190- 1300	30

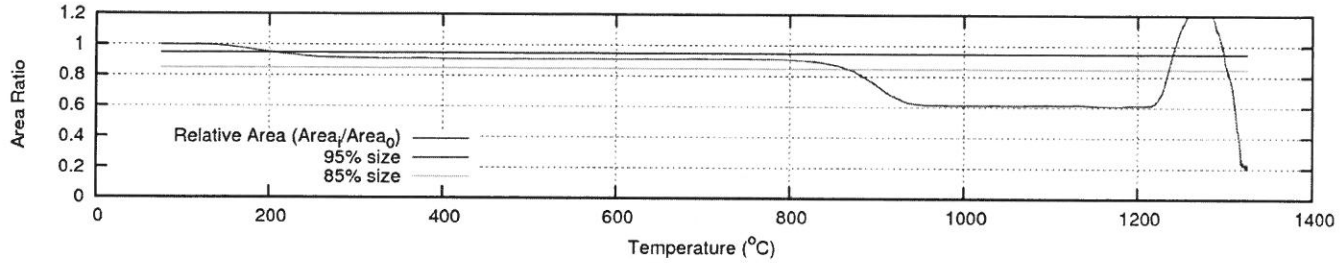
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

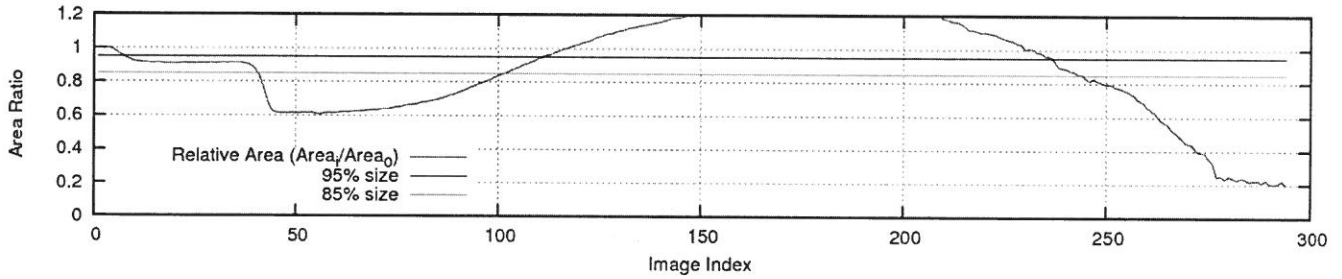
Images index	*Temperature*	*Images/min*
1 – 59	75 - 1216	0.5
59 – 294	1216 – 1326	21.38



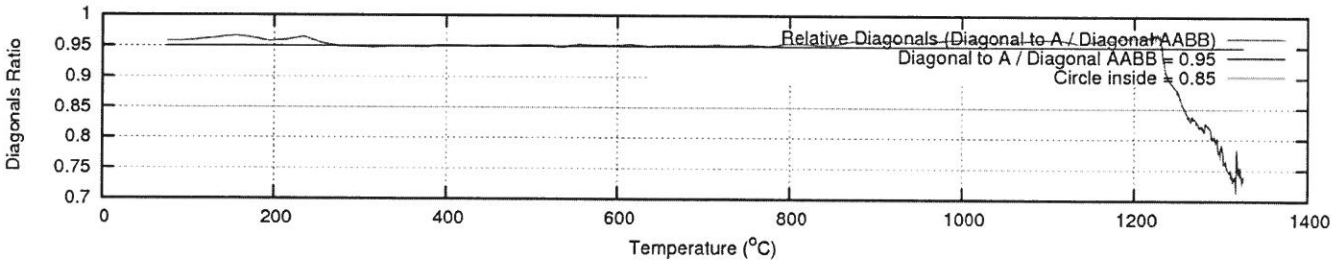
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

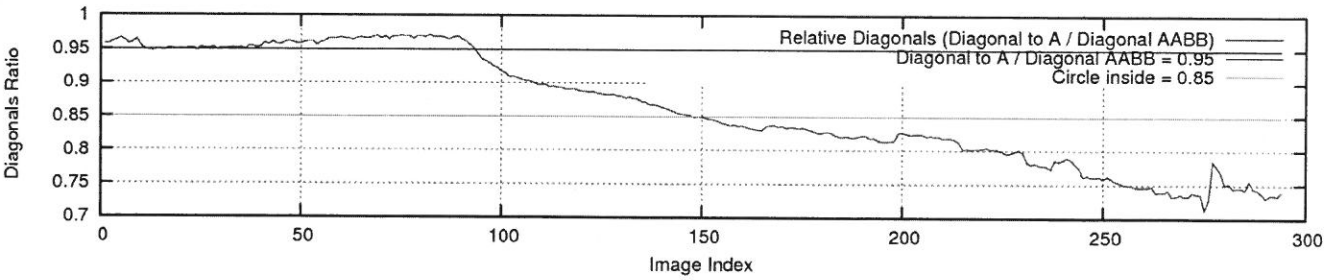


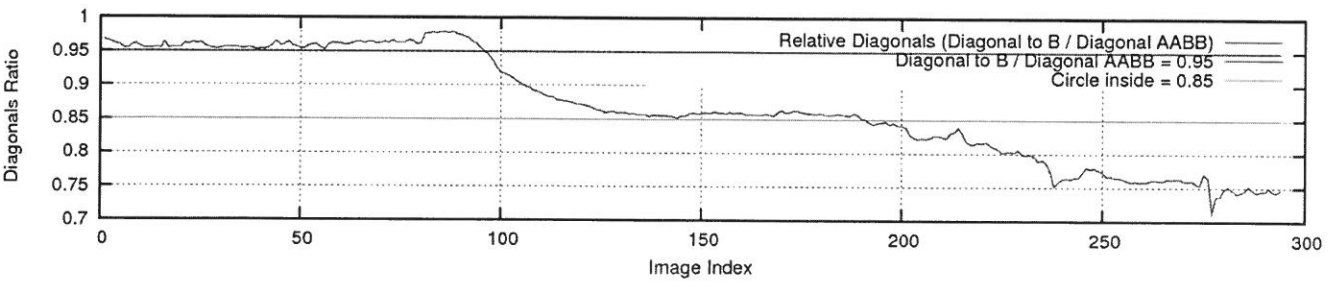




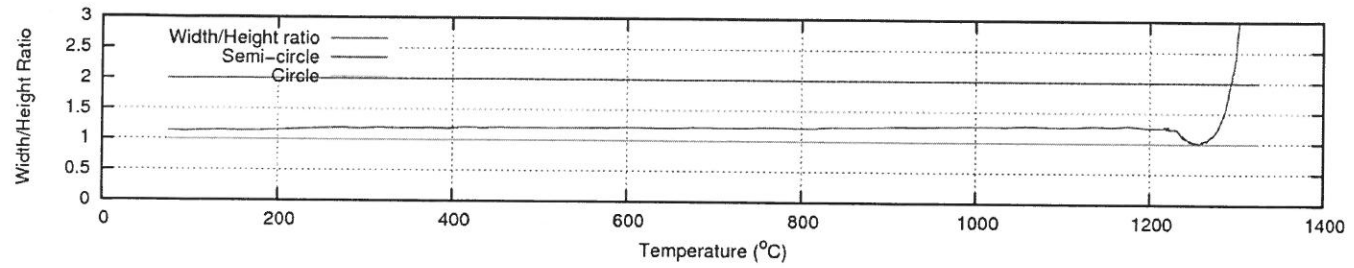
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

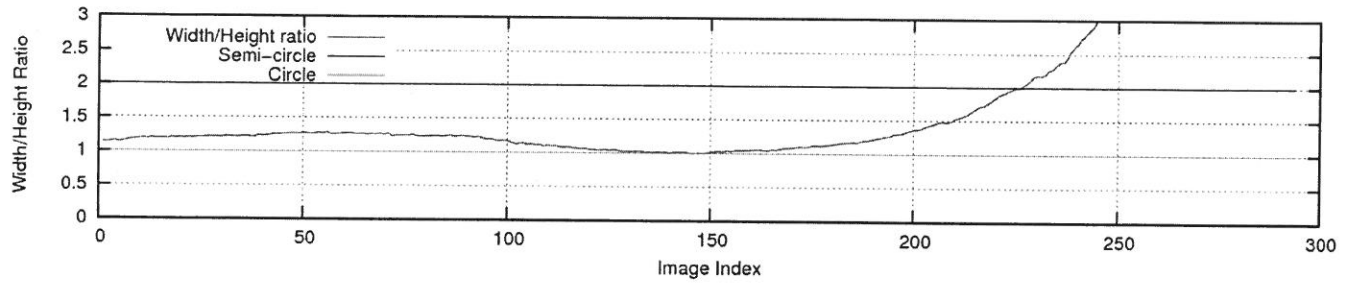


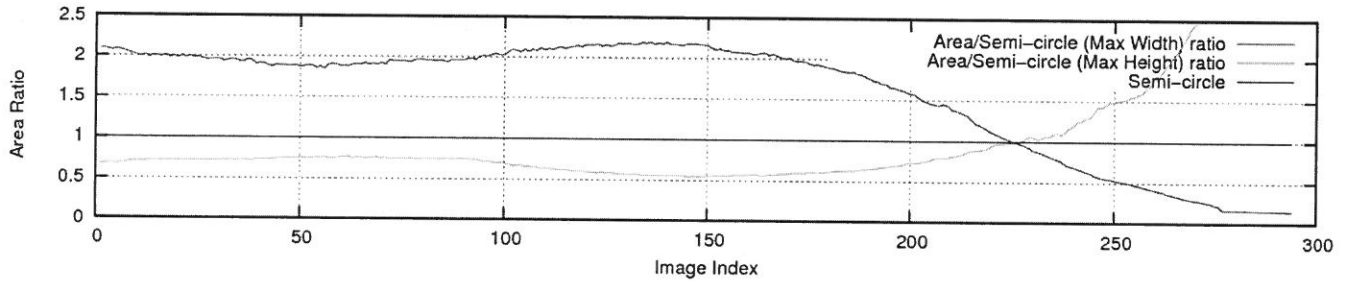




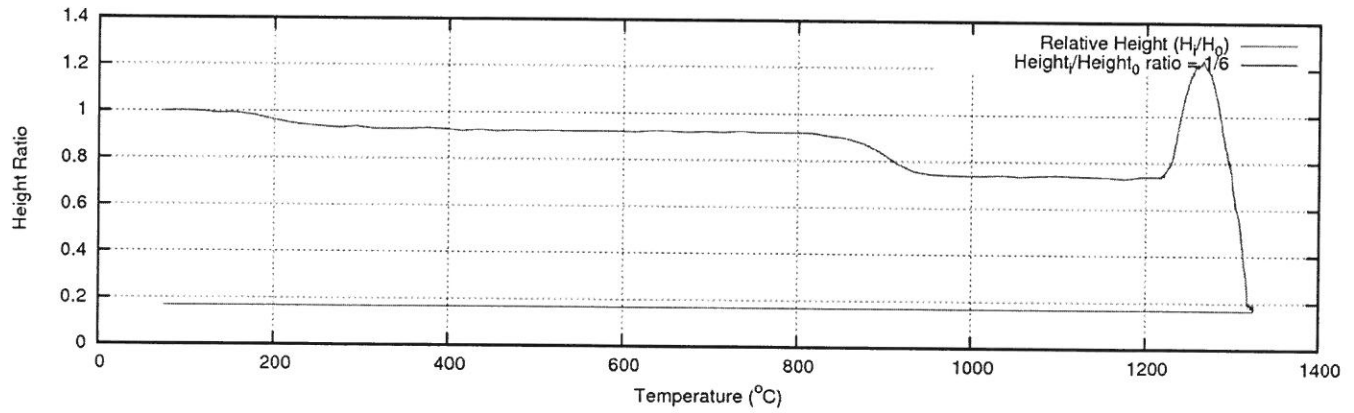
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

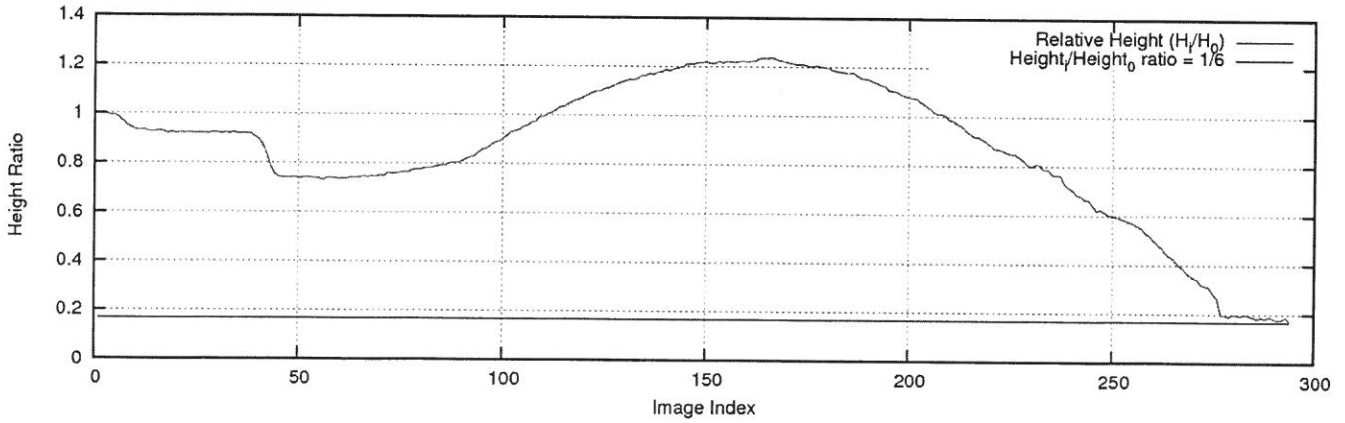




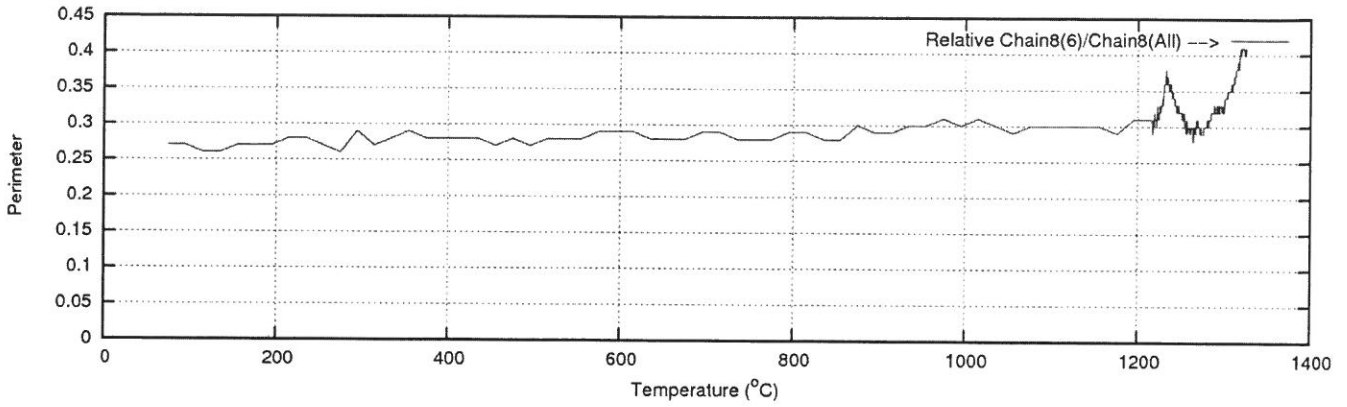


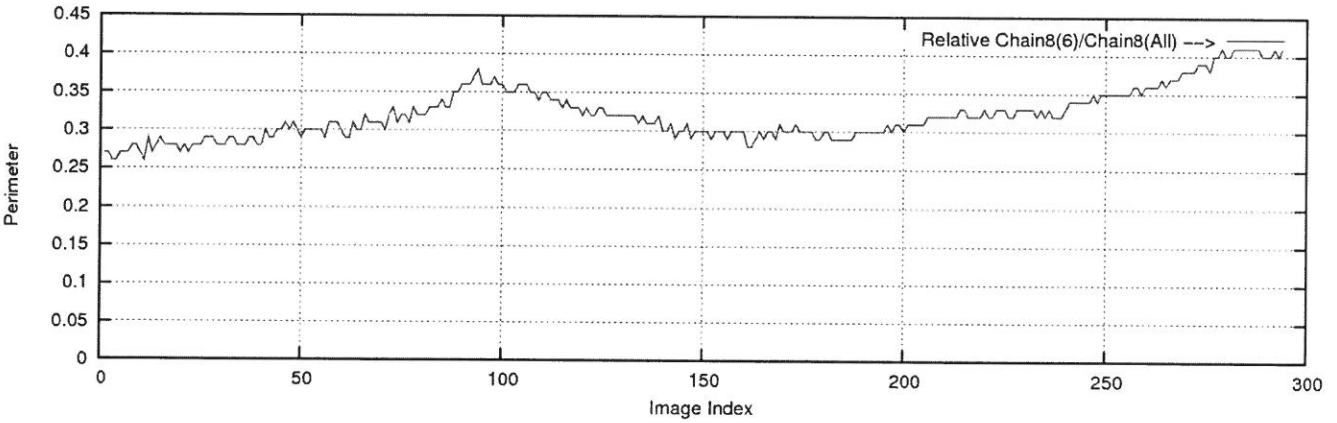
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





Dataset: T-24P

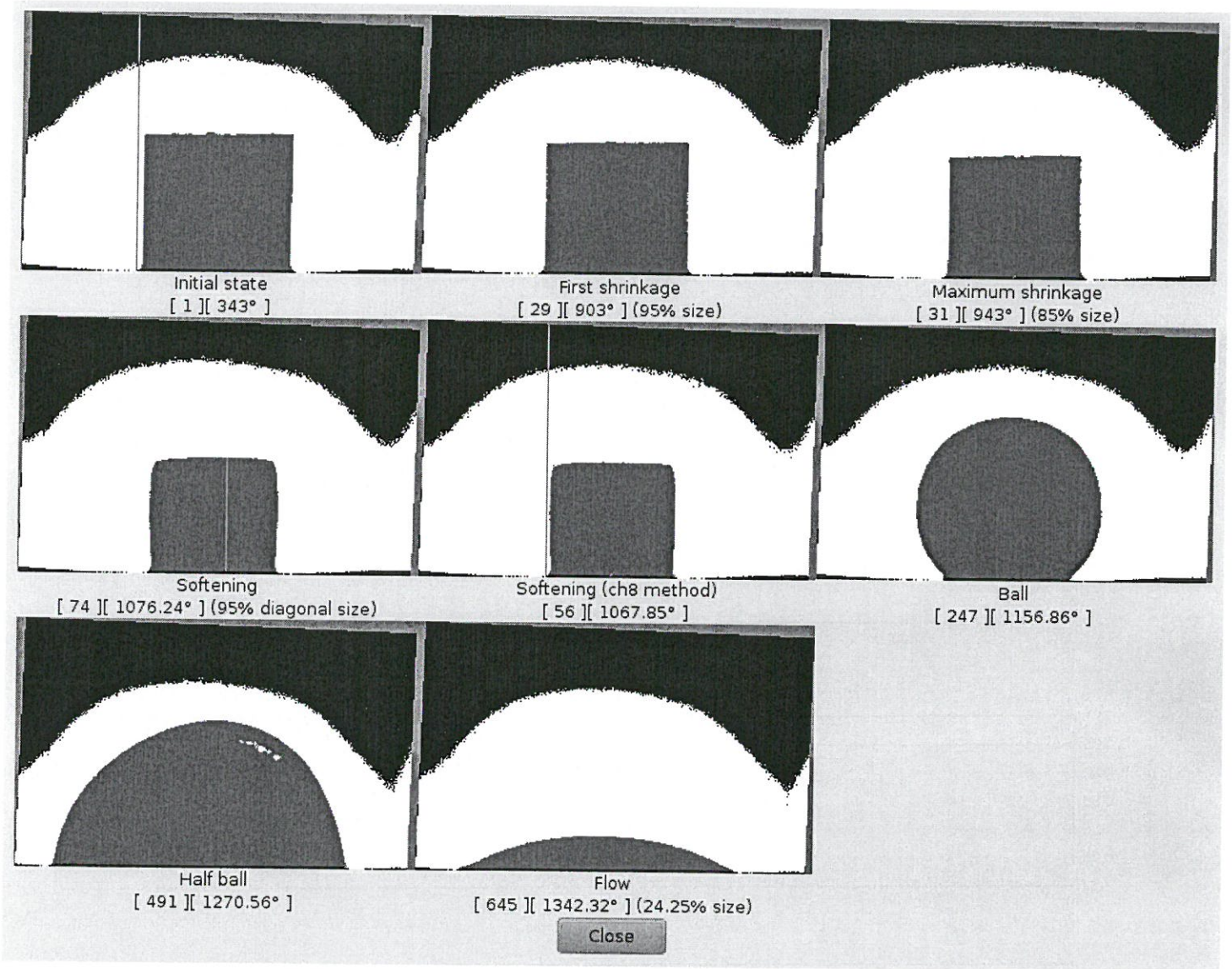
Repetir 24P

Temperature increment: 10°C/min

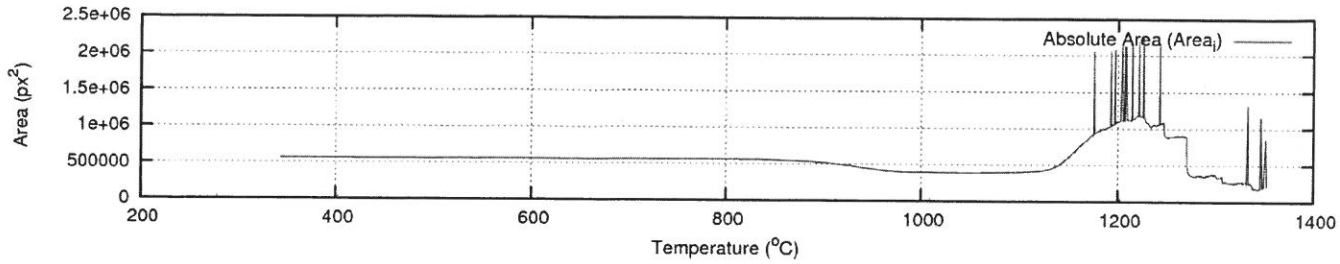
Images index	*Temperature*	*Images/min*
1 – 37	343 - 1059	0.5
37 – 667	1059 - 1351	30

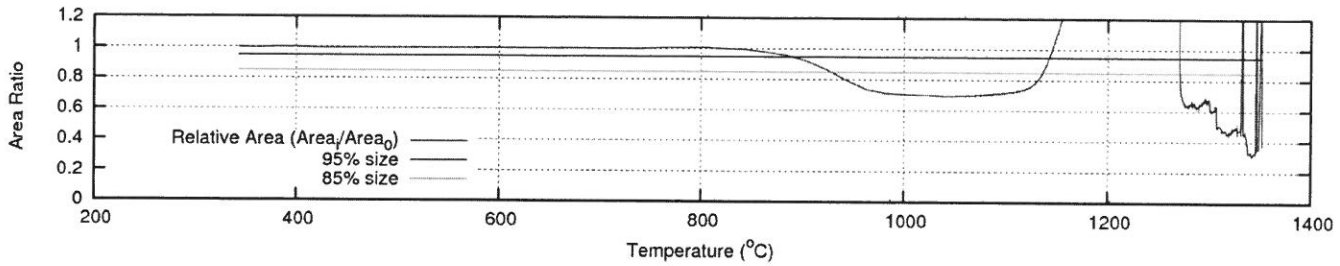
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

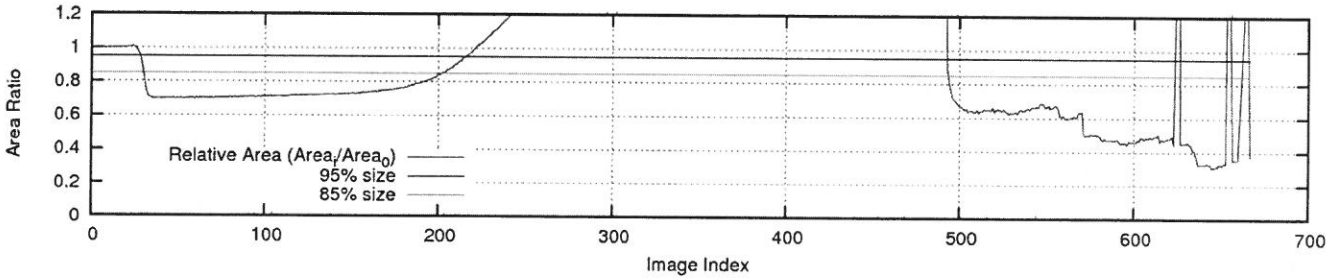
Images index	*Temperature*	*Images/min*
1 – 37	343 - 1059	0.5
37 – 667	1059 - 1353	21.46



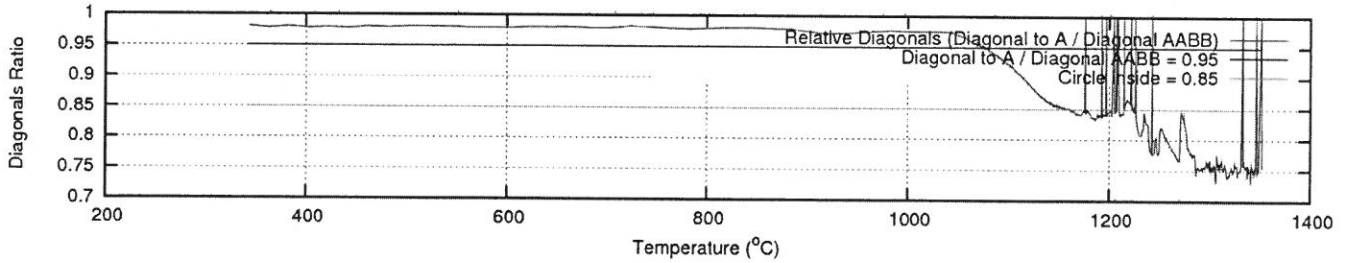
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

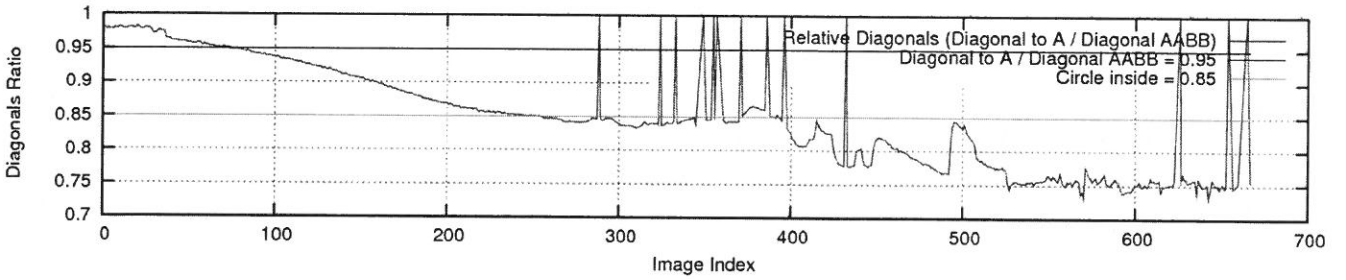


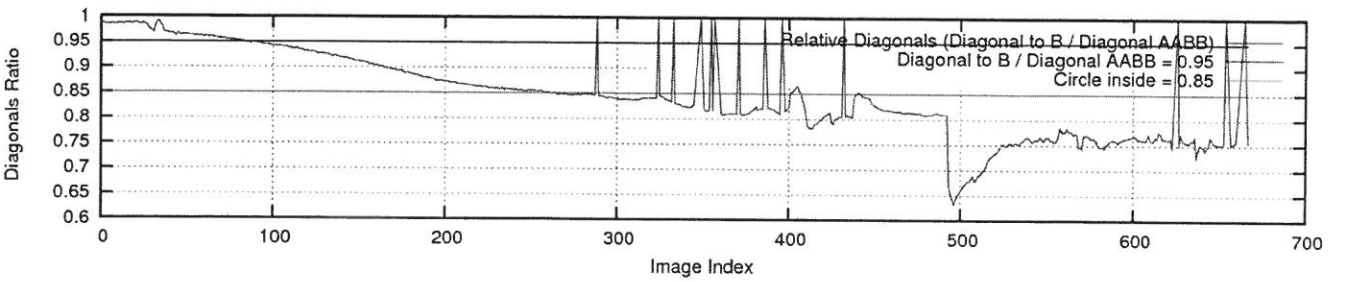




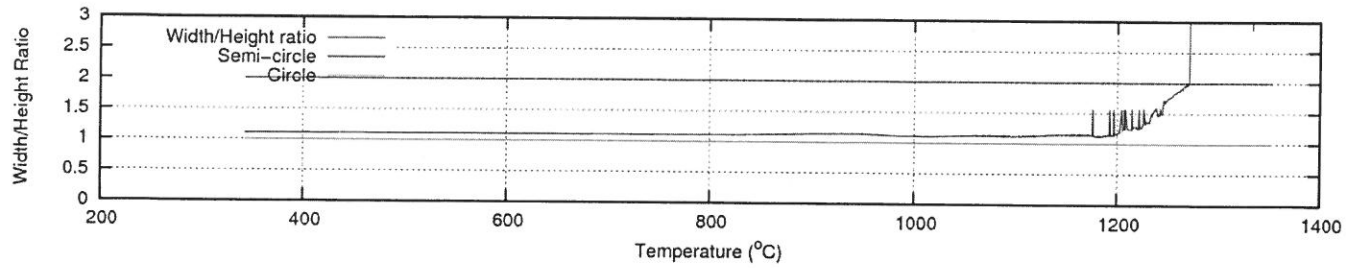
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

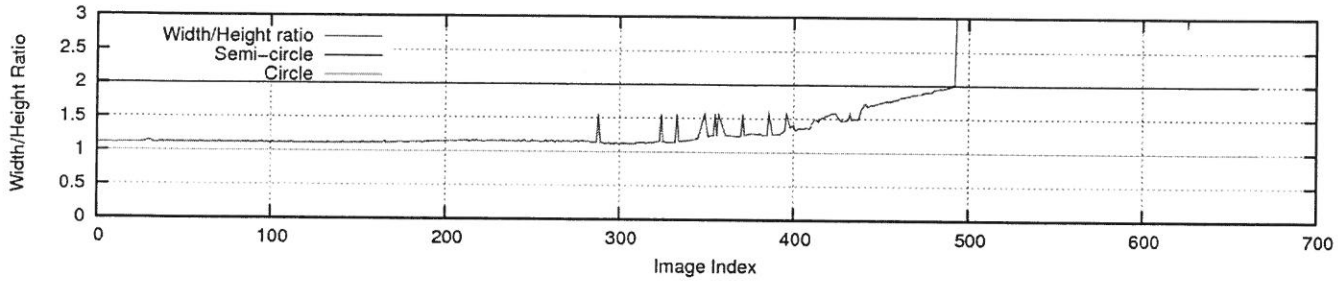


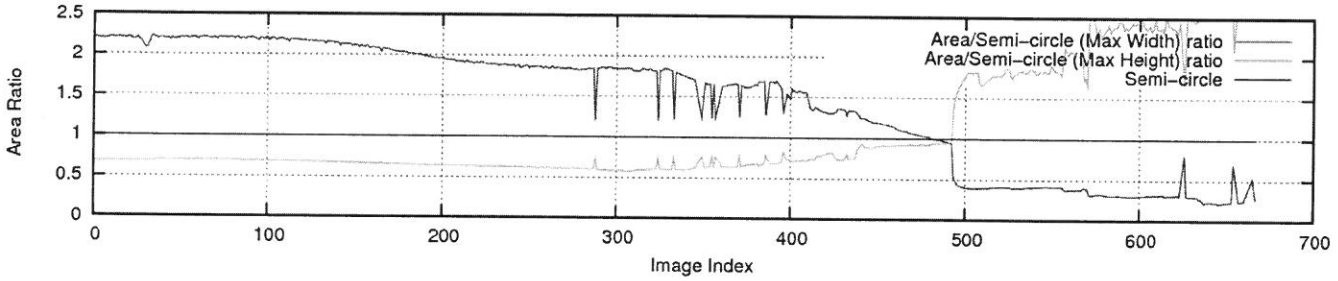




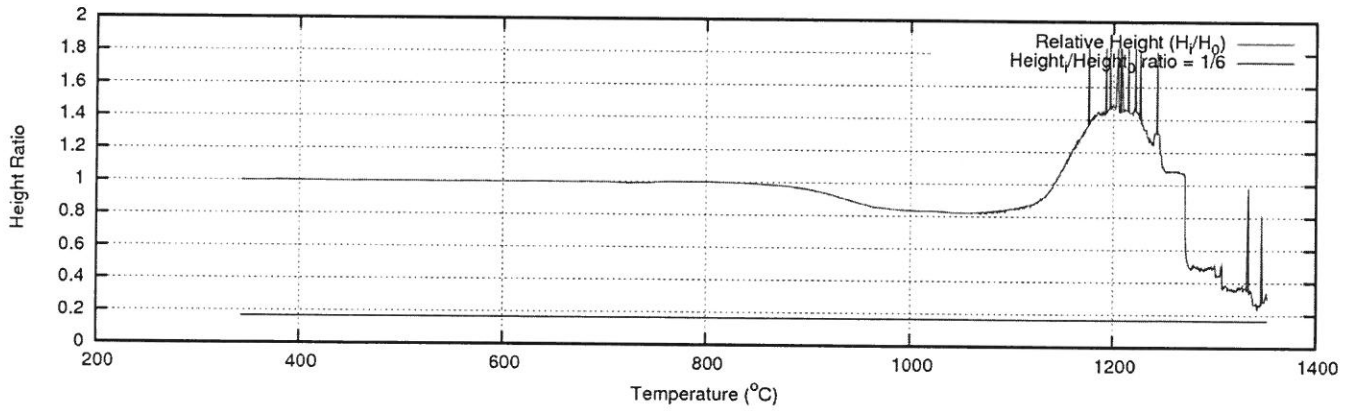
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

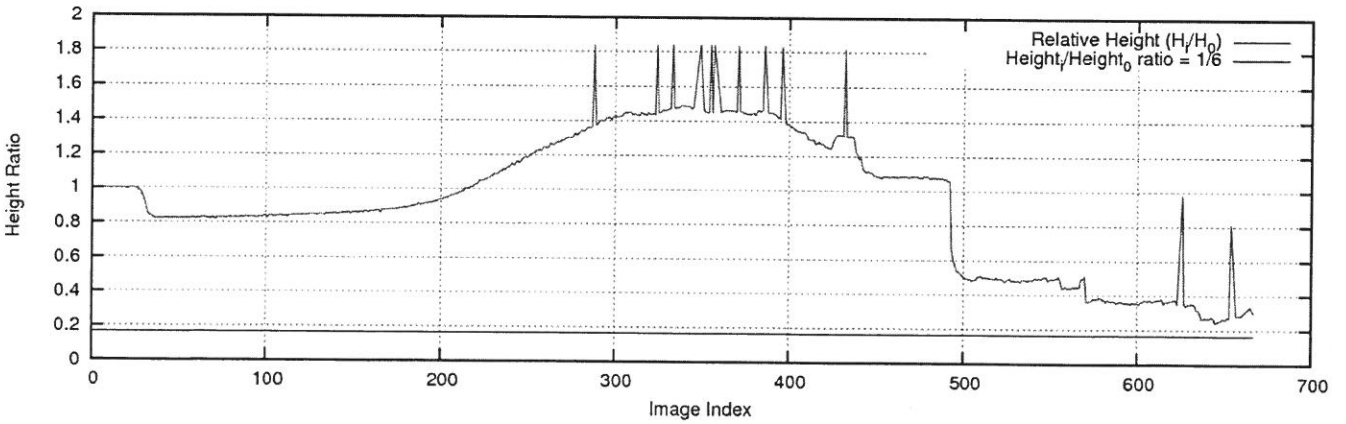




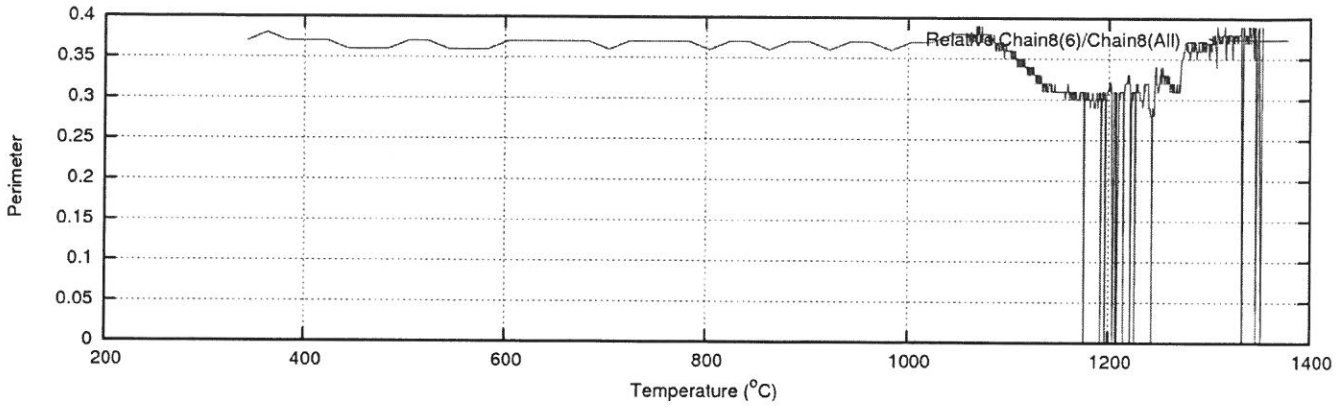


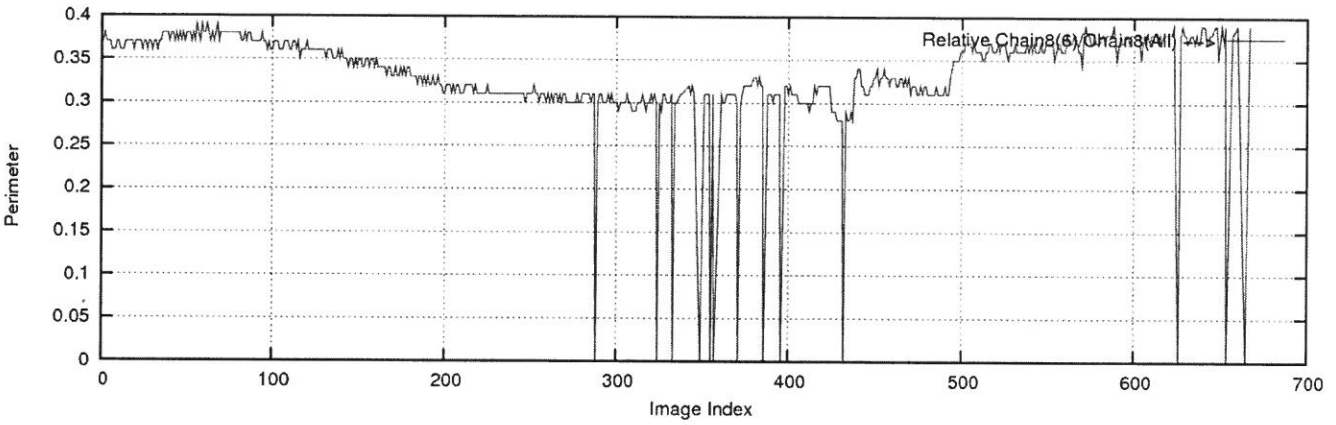
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





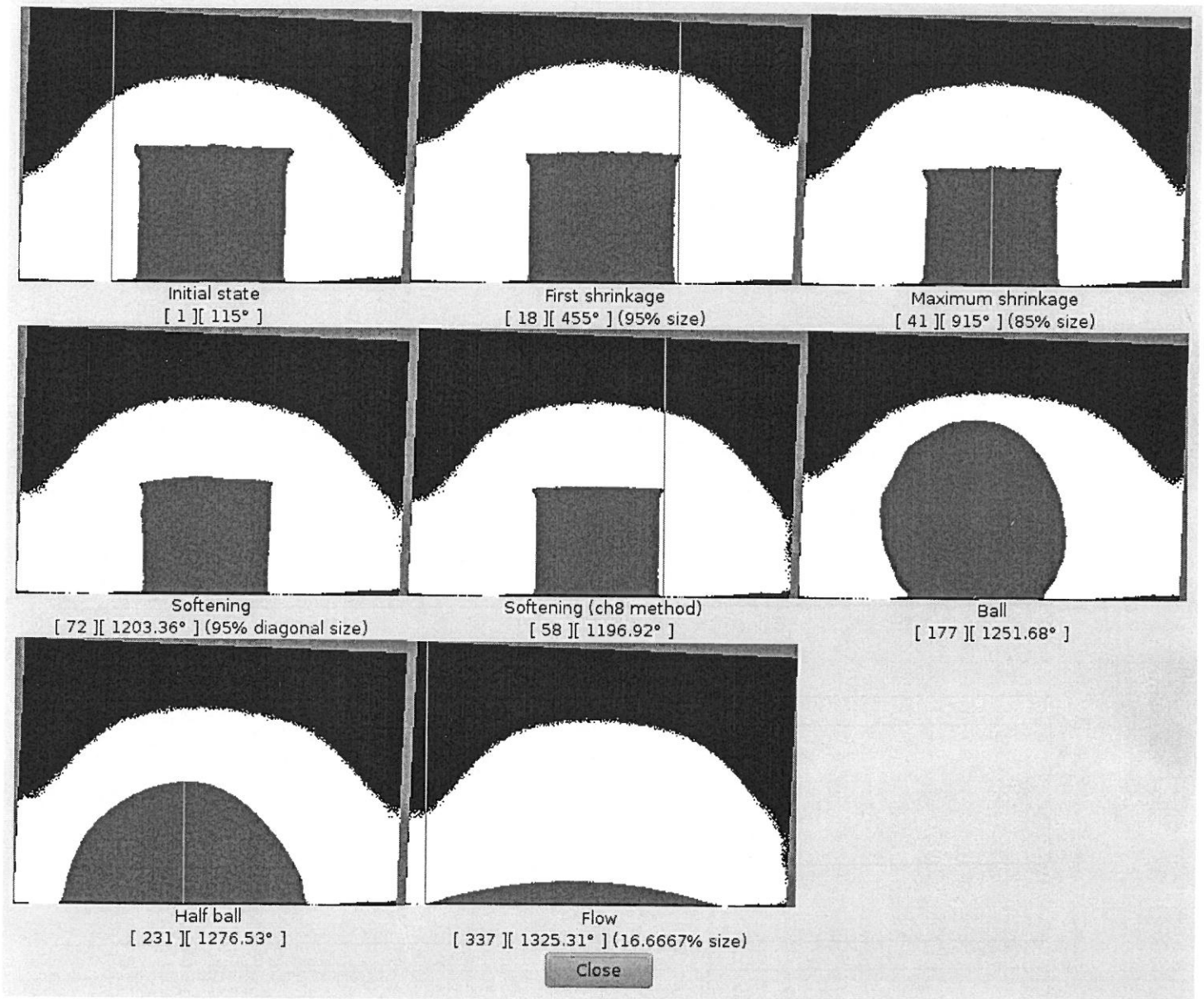
Dataset: T-2P

Temperature increment: 10°C/min

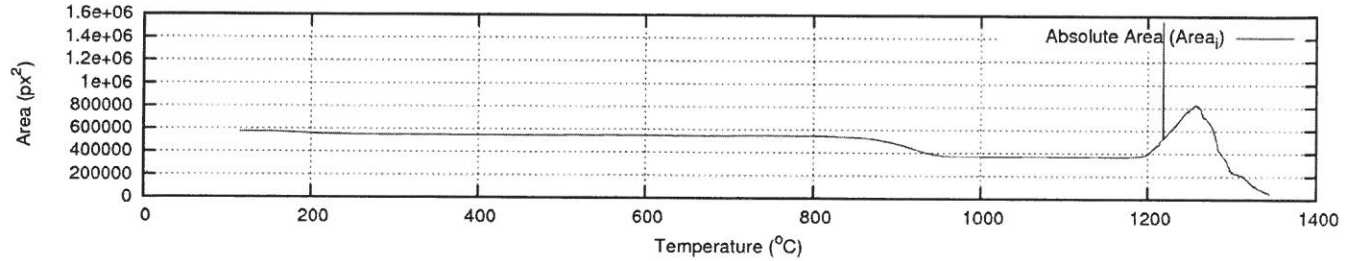
Images index	*Temperature*	*Images/min*
1 – 55	117 - 1194	0.5
55 – 380	1194- 1346	30

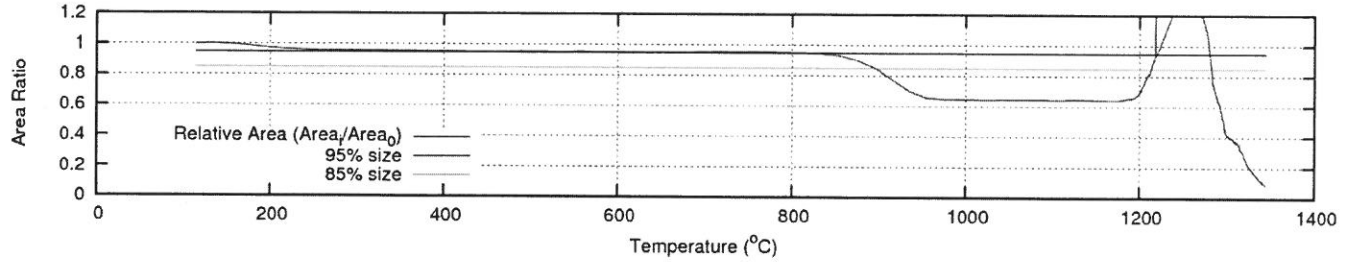
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

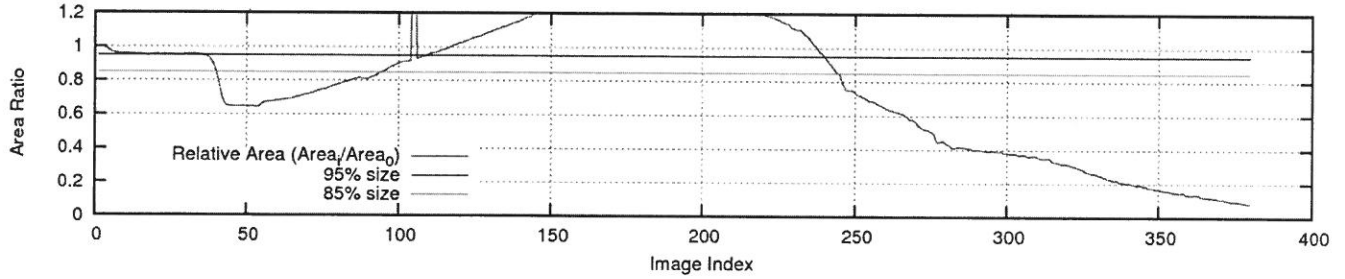
Images index	*Temperature*	*Images/min*
1 – 56	115 - 1196	0.5
56 – 380	1196- 1345	21.73



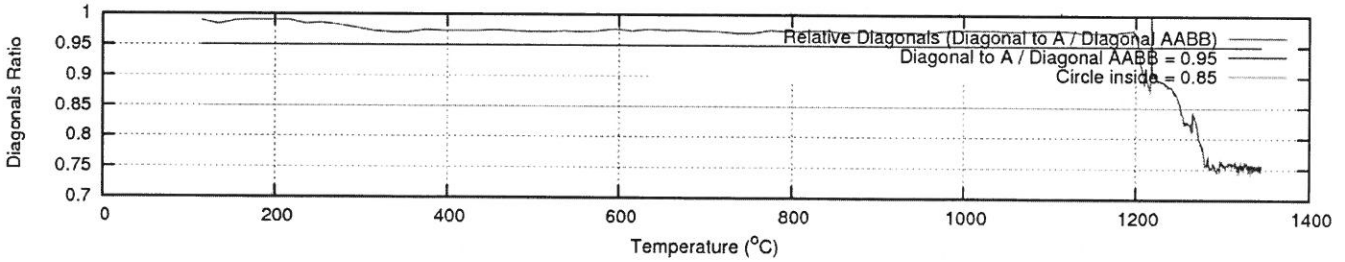
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

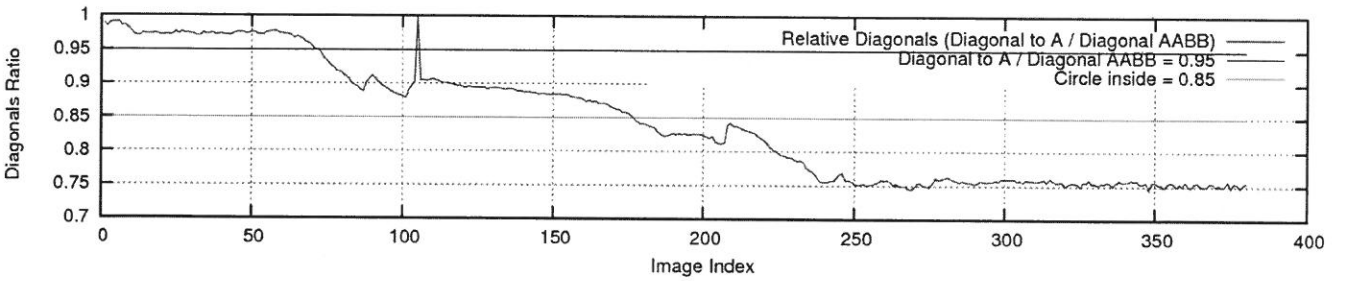


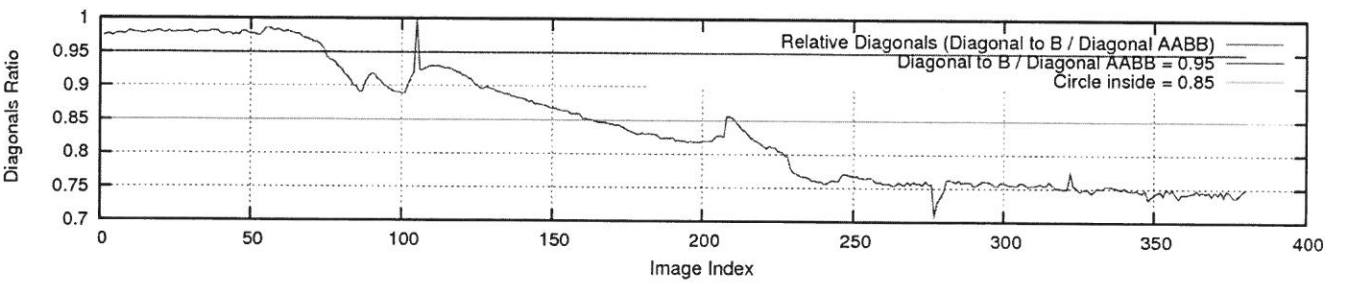




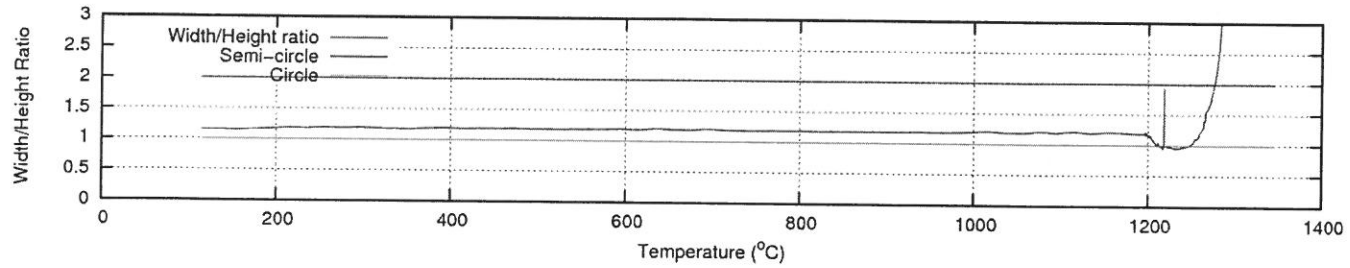
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

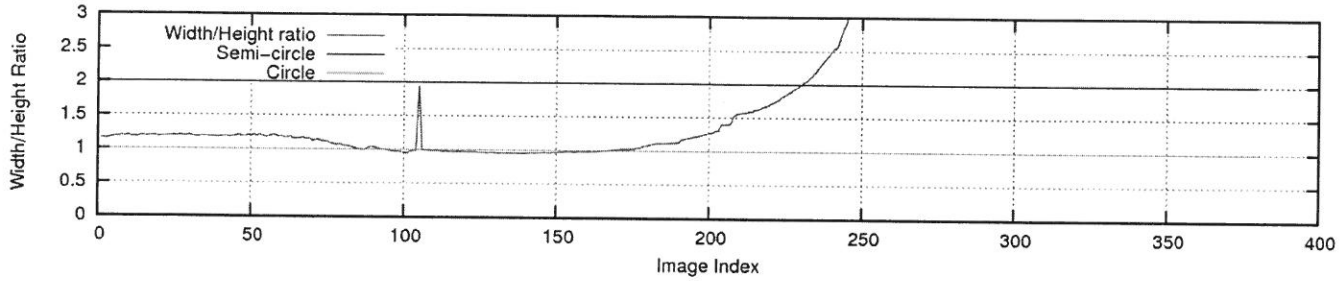


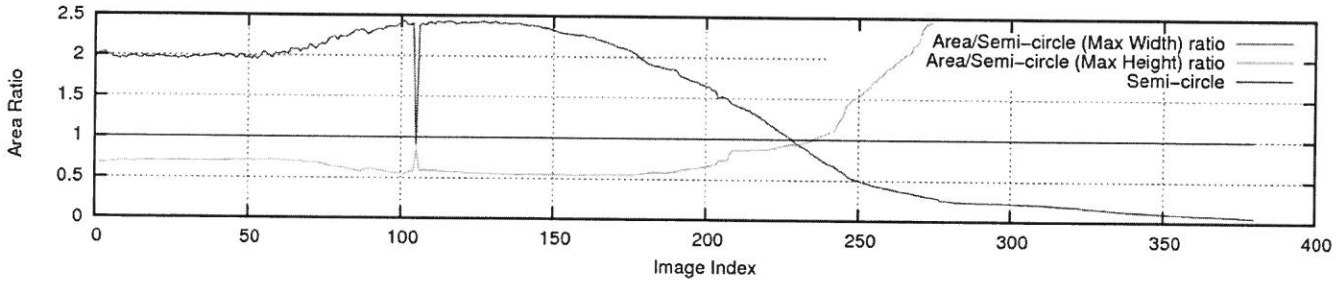




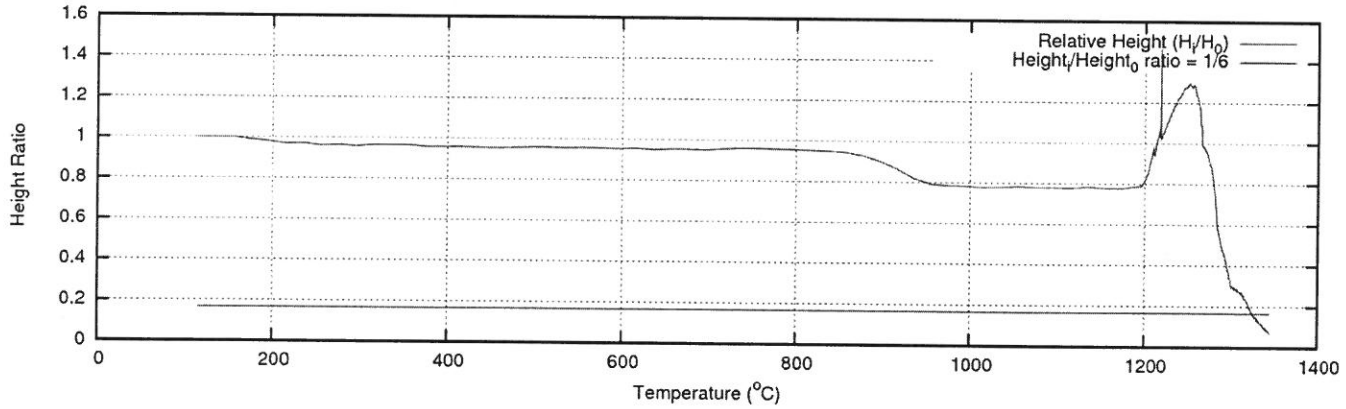
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

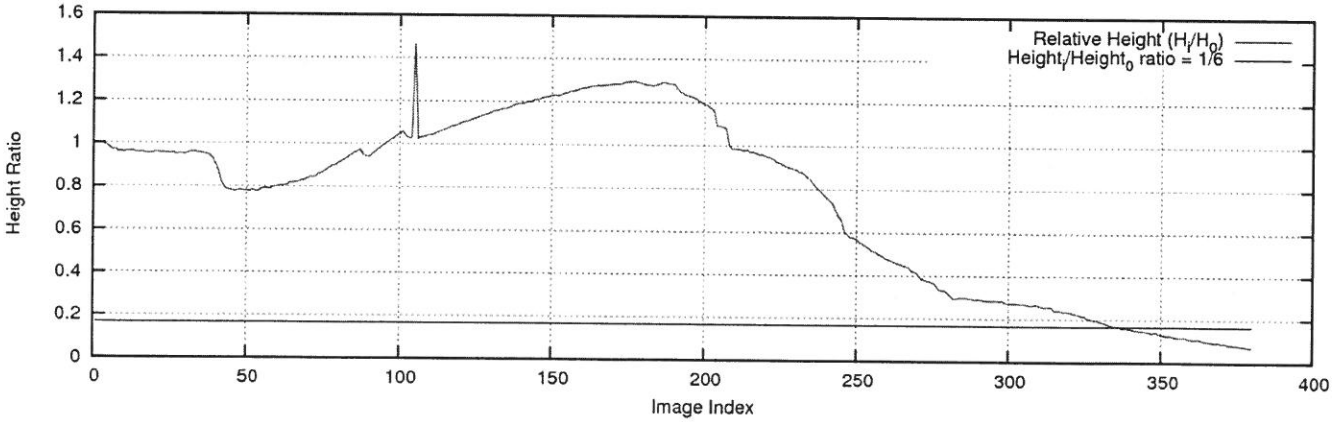




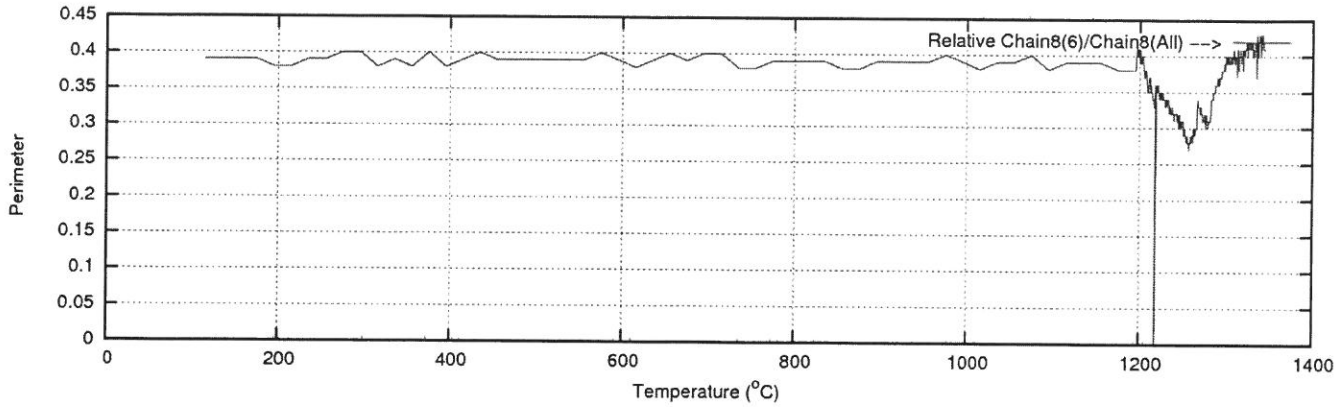


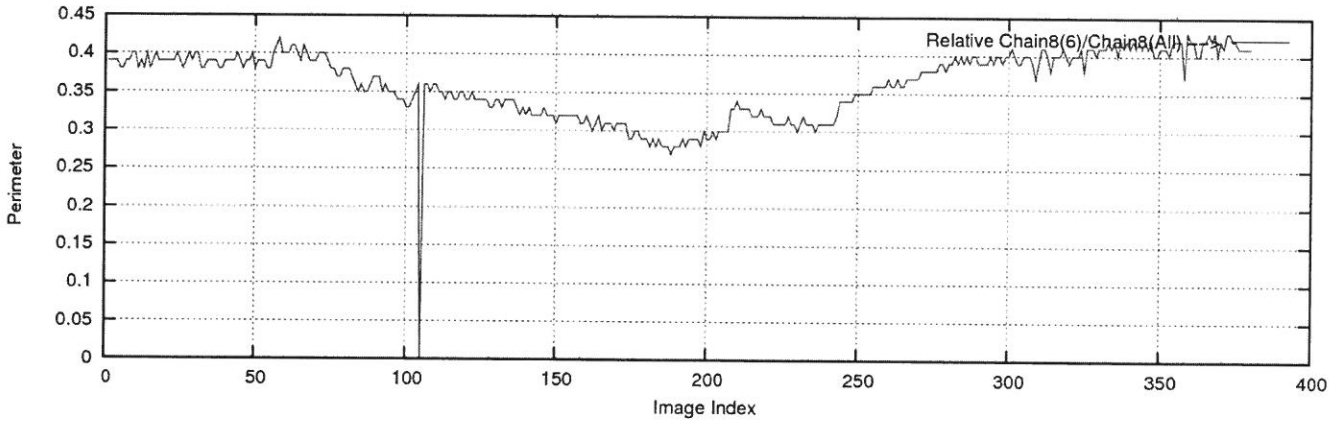
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





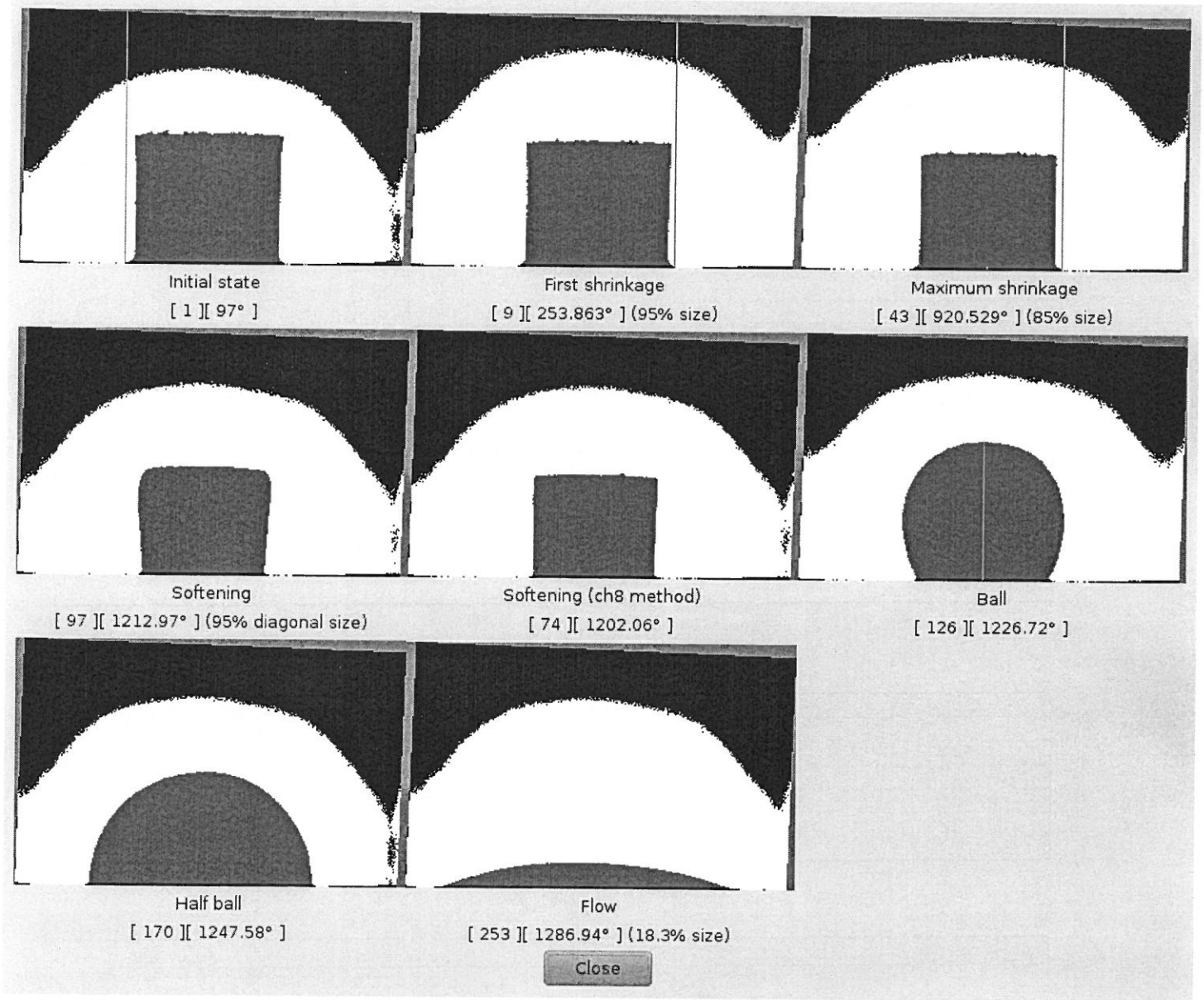
Dataset: T-4P

Temperature increment: 10°C/min

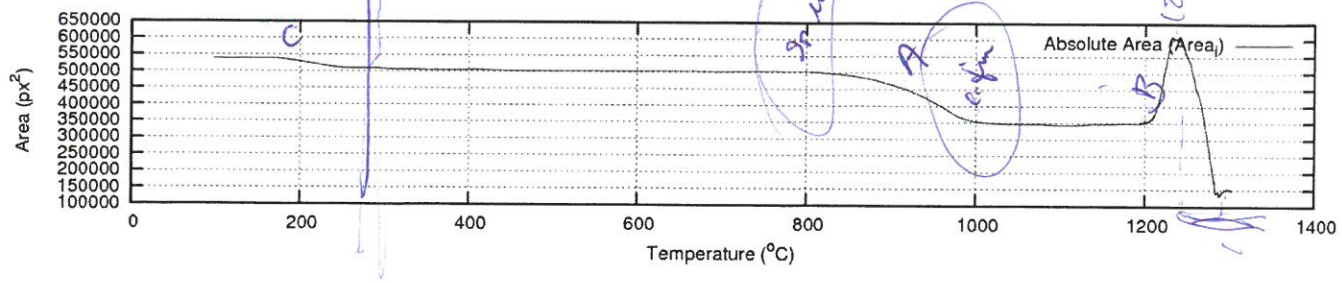
Images index	*Temperature*	*Images/min*
1 – 57	100 - 1193	0.5
57 – 285	1193 -1302	30

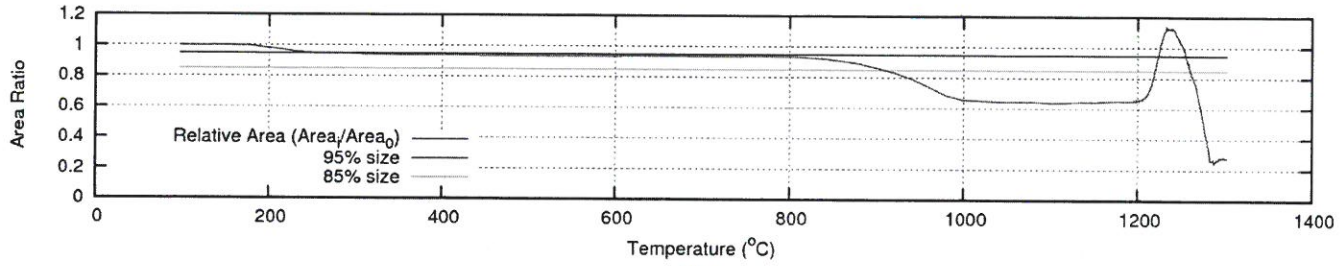
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

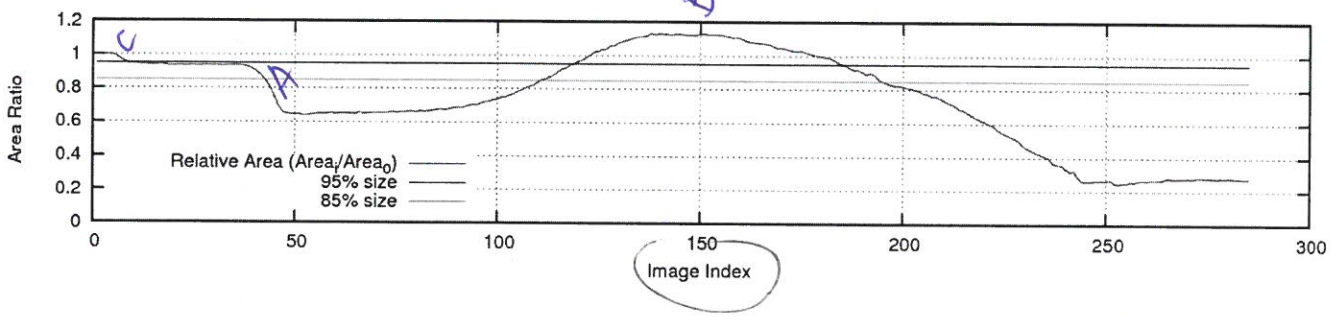
Images index	*Temperature*	*Images/min*
1 – 57	97 - 1194	0.51
57 – 285	1194 -1302	21.09



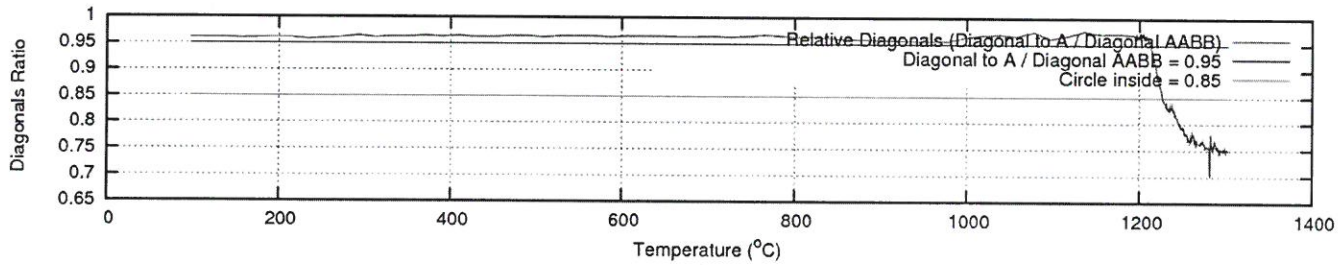
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

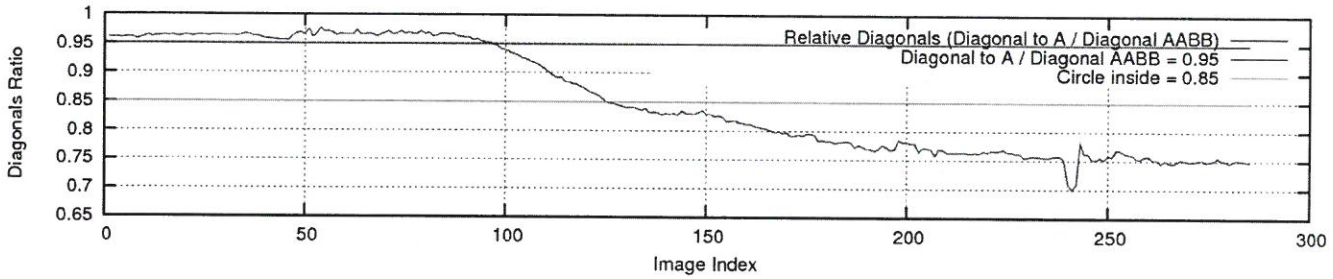


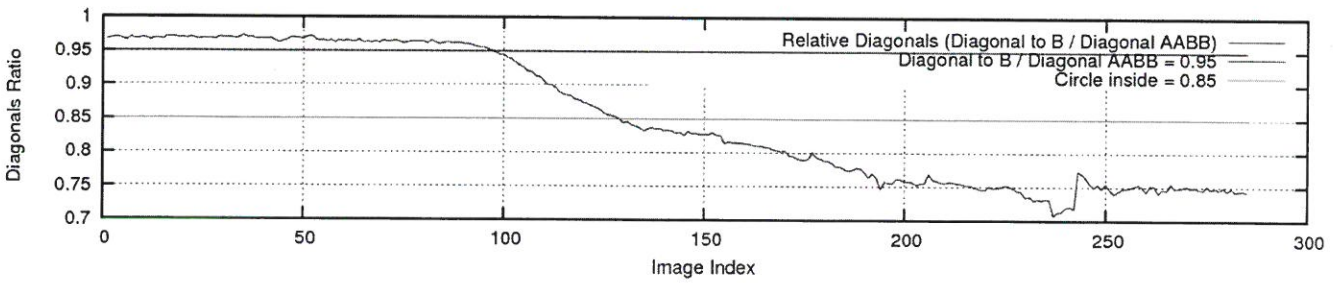




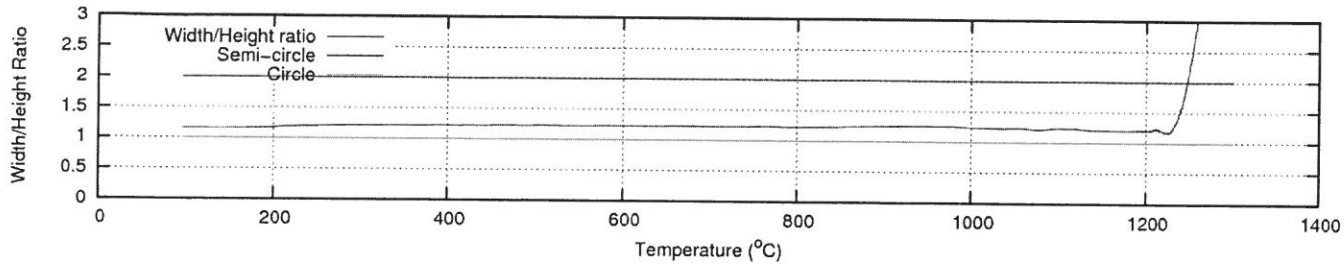
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

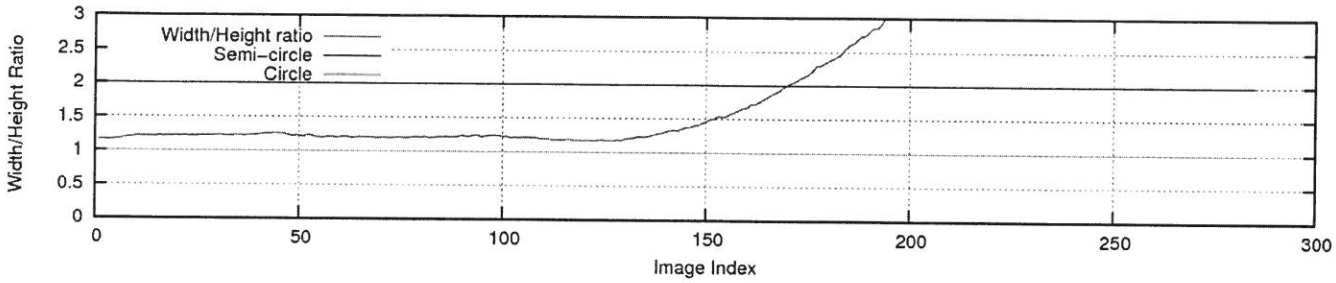


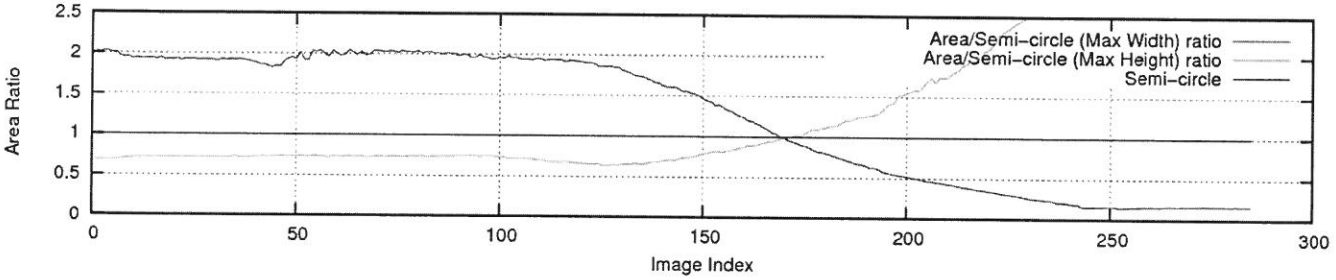




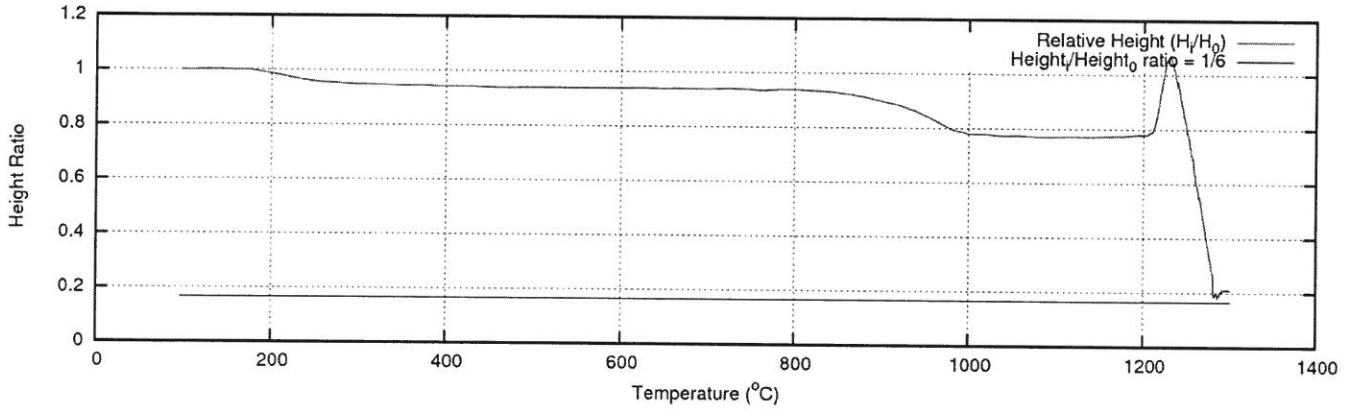
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

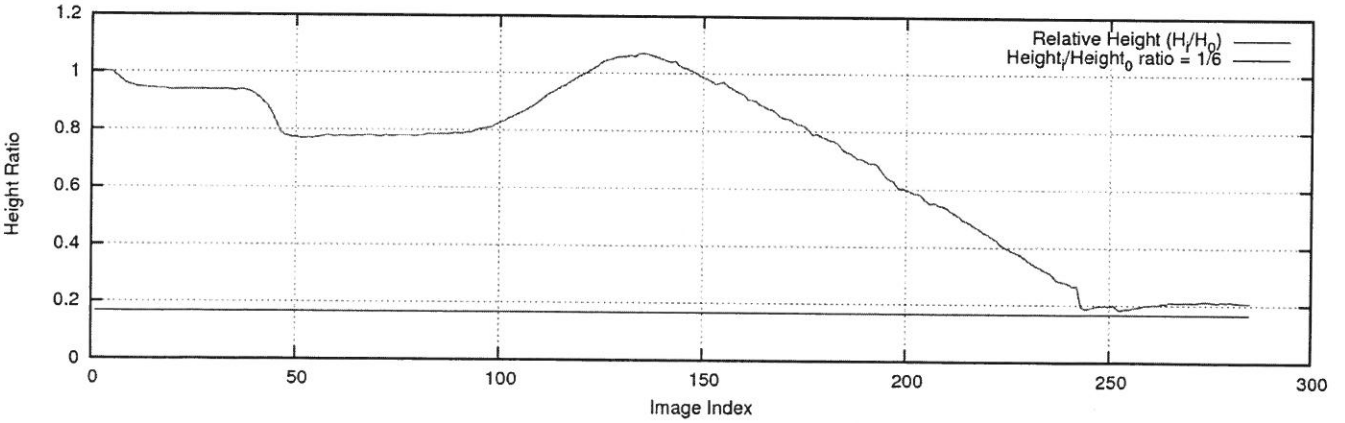




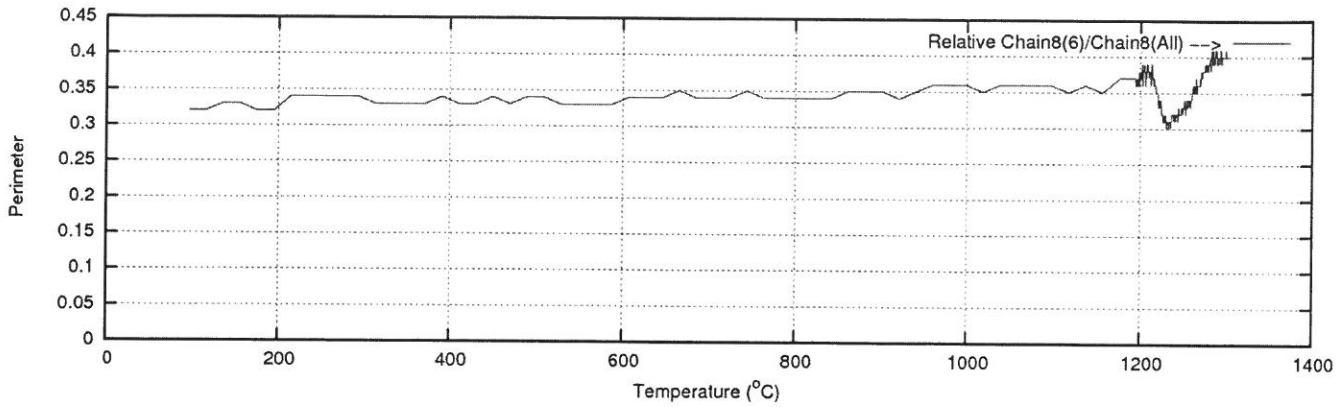


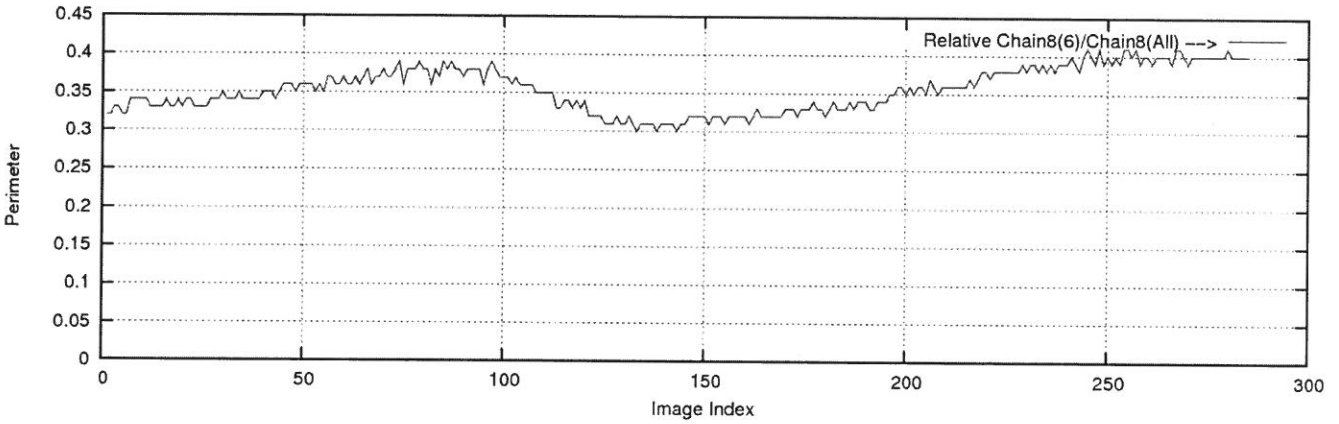
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





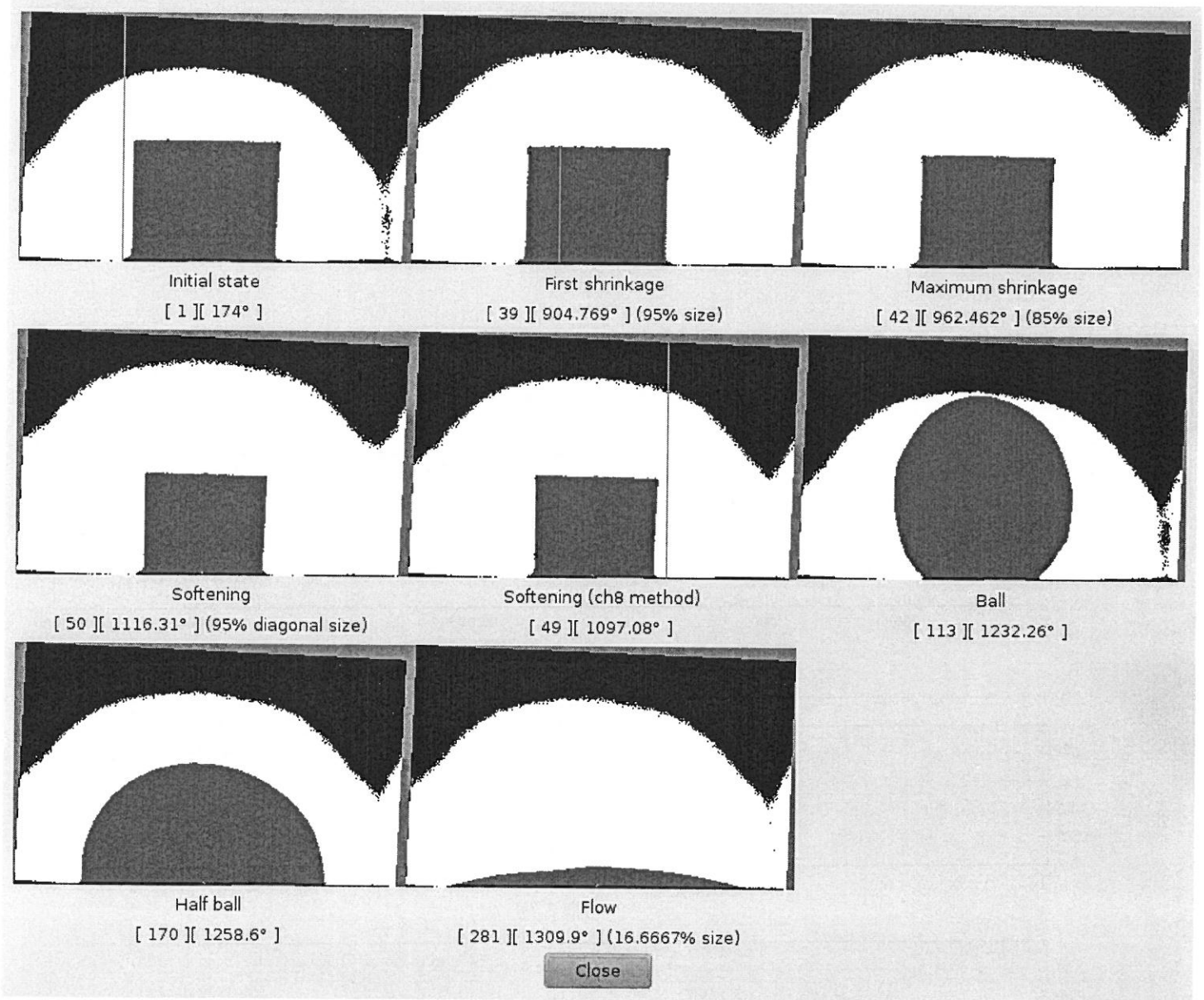
Dataset: T-8P

Temperature increment: 10°C/min

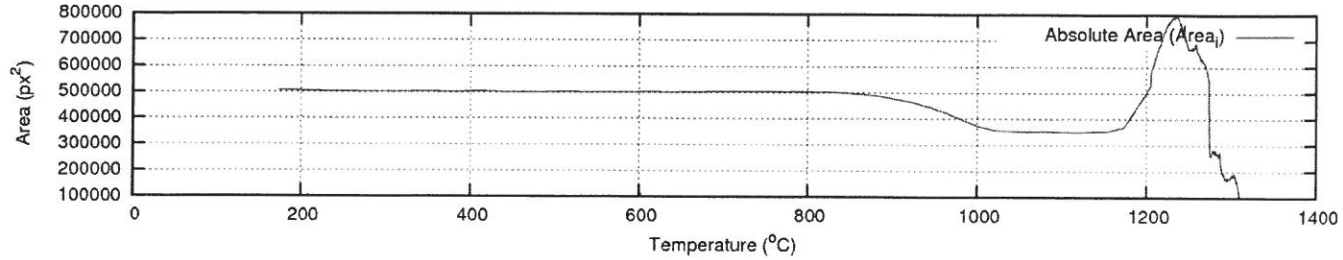
Images index	*Temperature*	*Images/min*
1 – 54	174 - 1202	0.5
54 – 279	1202 -1308	30

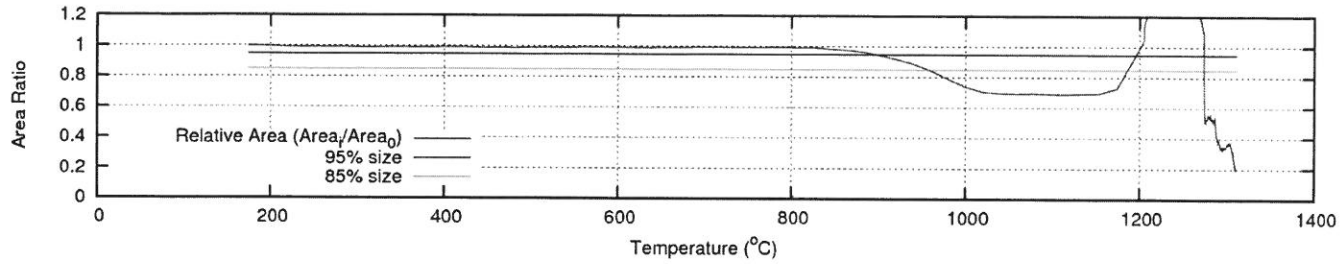
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

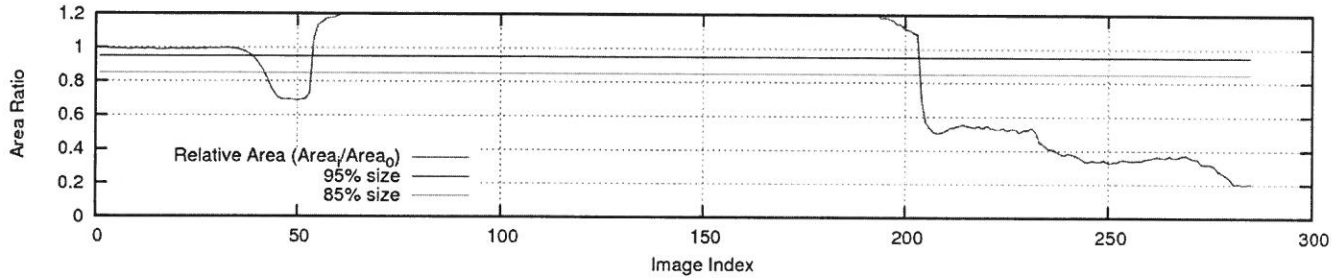
Images index	*Temperature*	*Images/min*
1 – 54	174 - 1205	0.52
54 – 285	1205 -1312	21.64



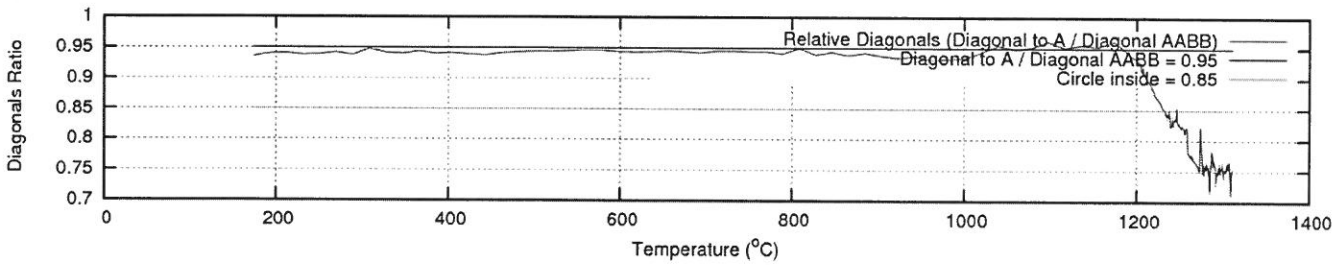
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

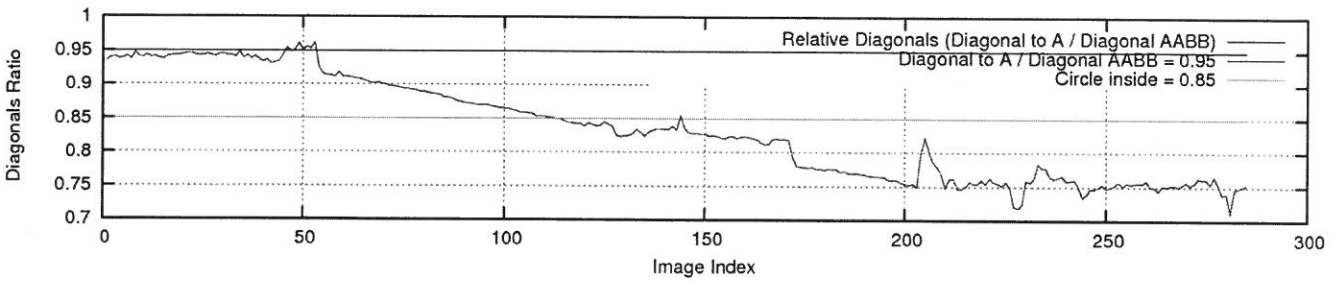


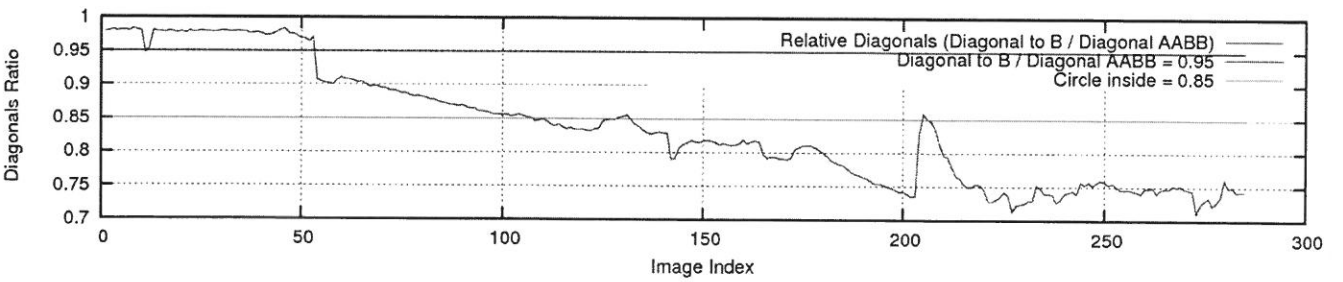




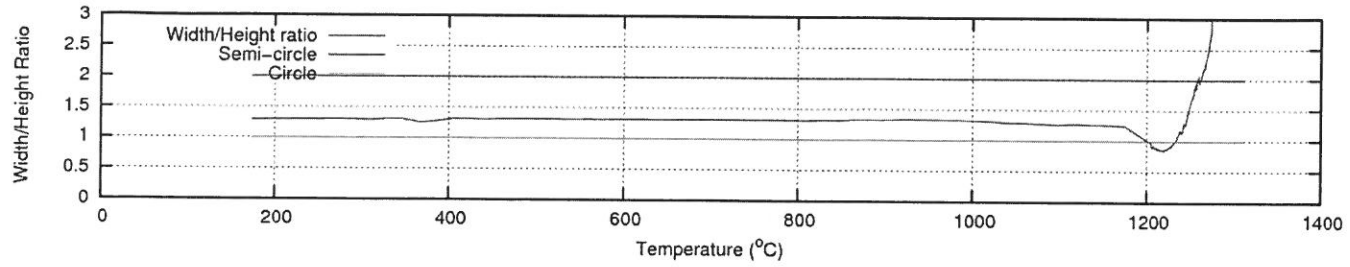
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

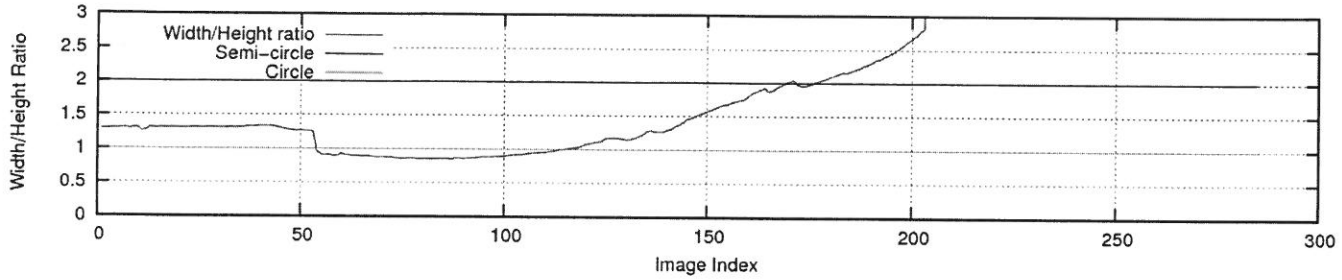


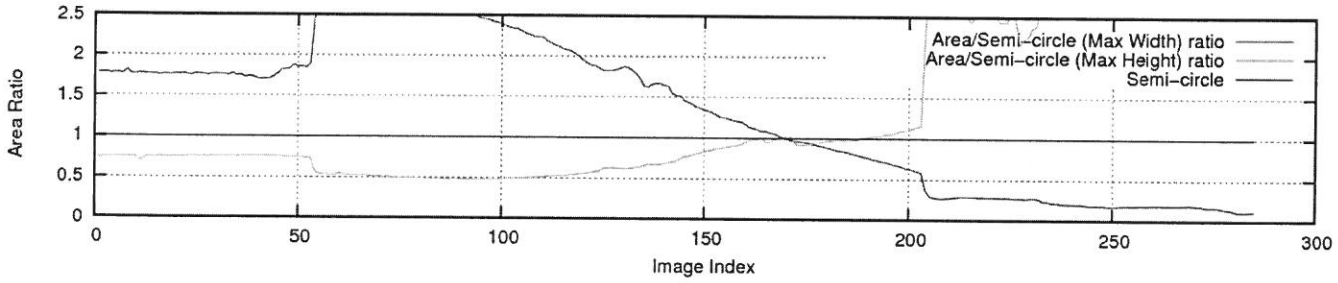




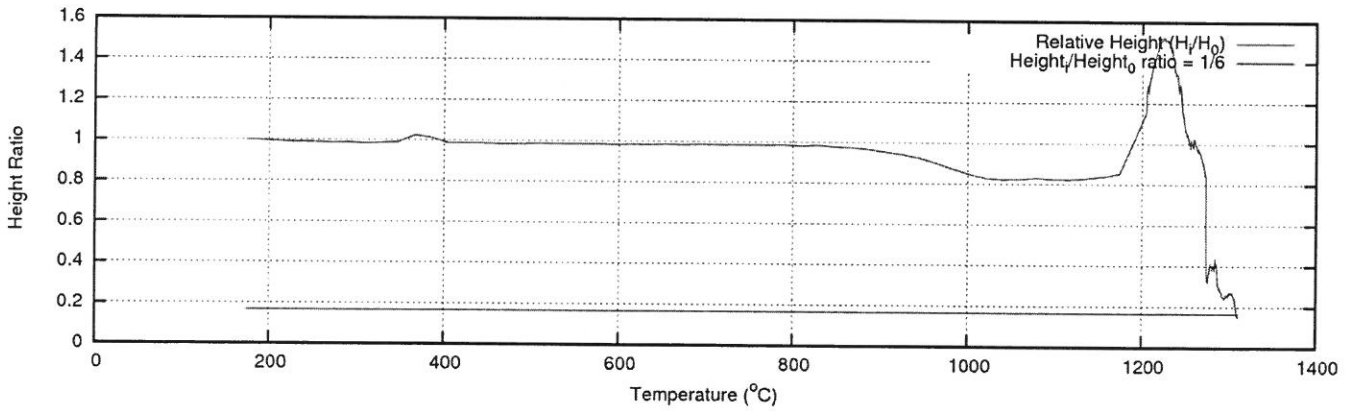
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

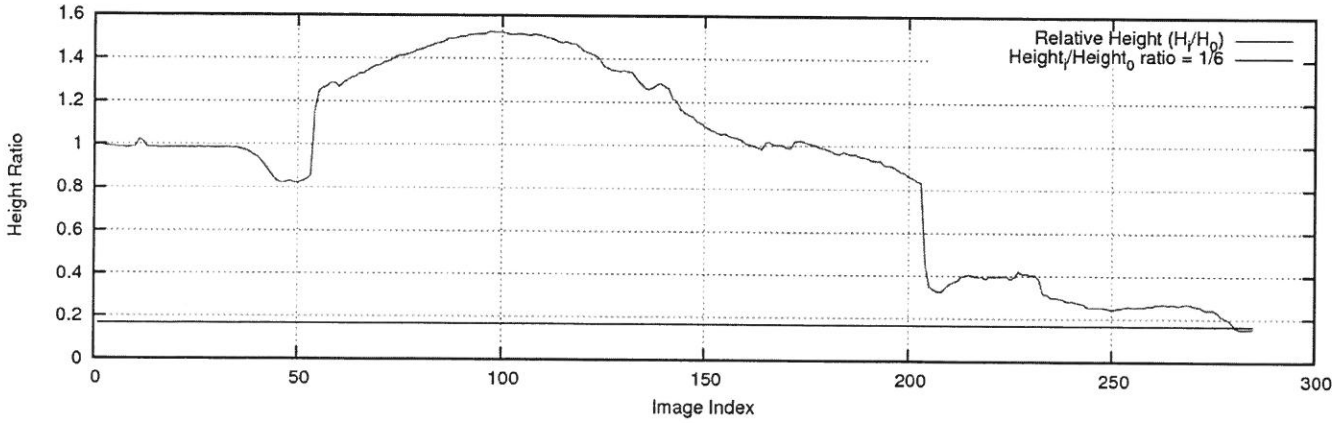




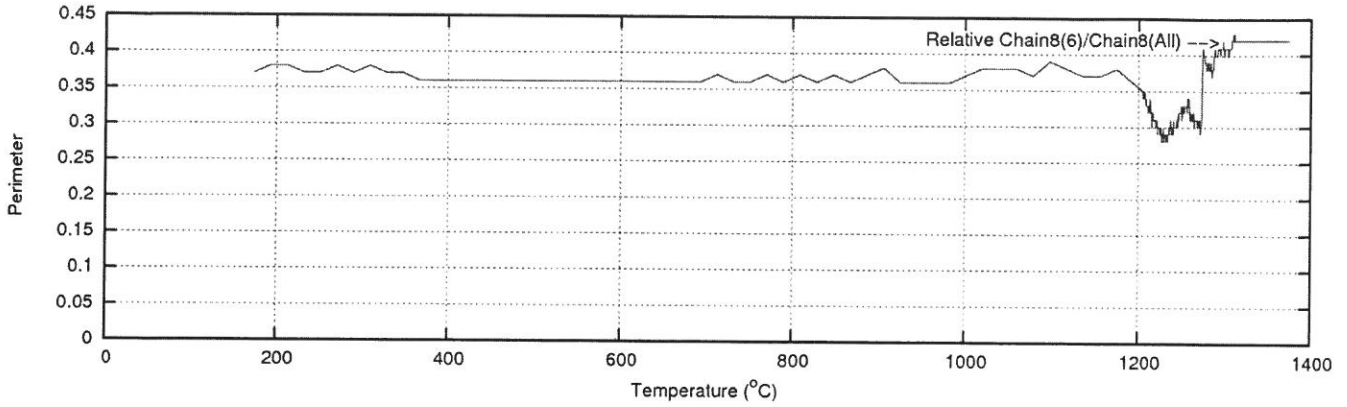


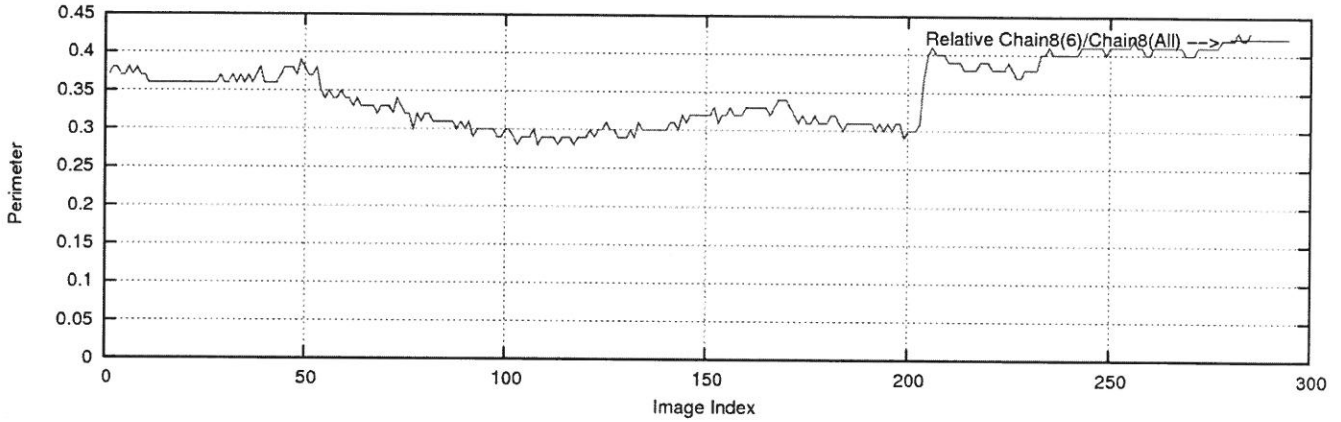
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)





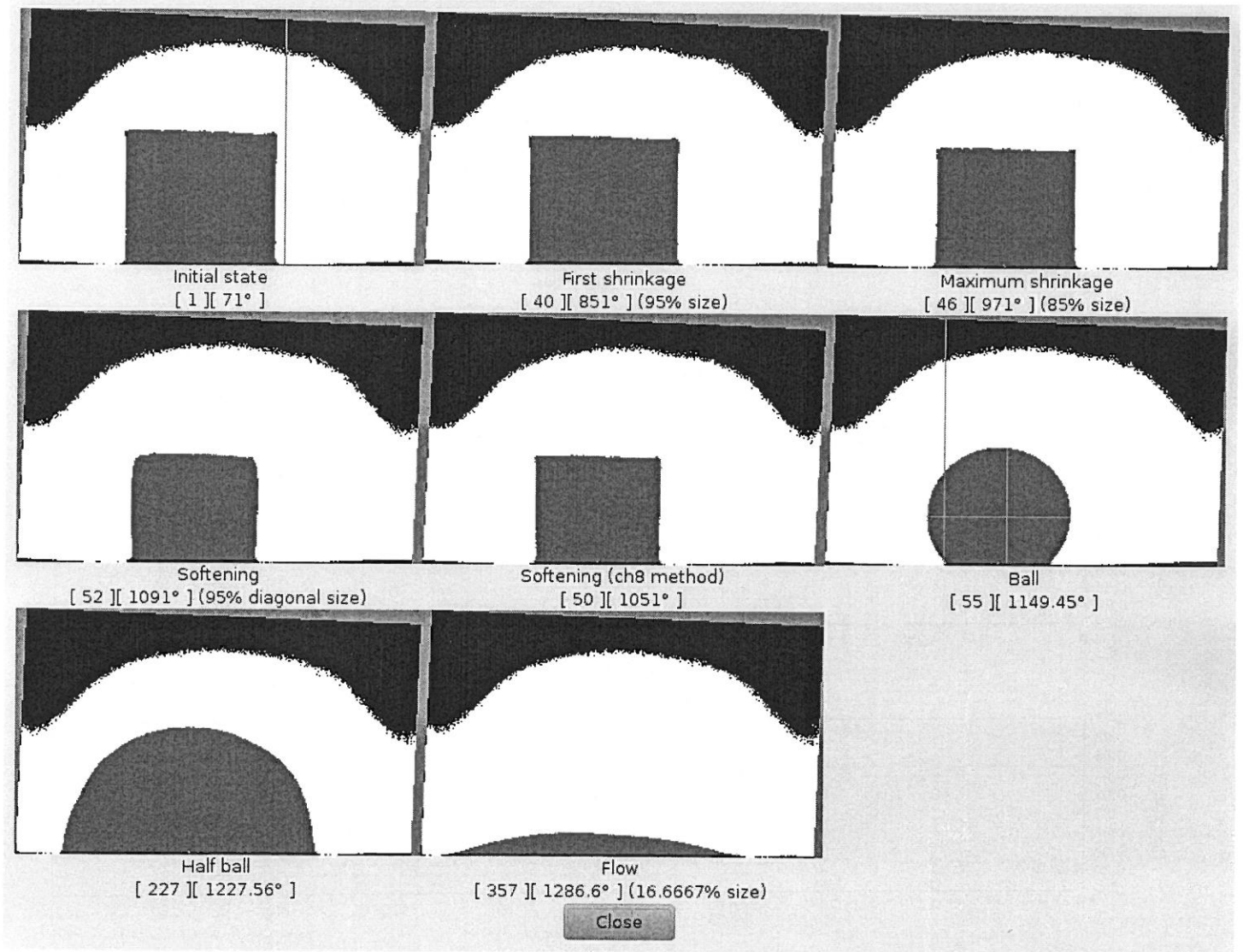
Dataset: T-16P

Temperature increment: 10°C/min

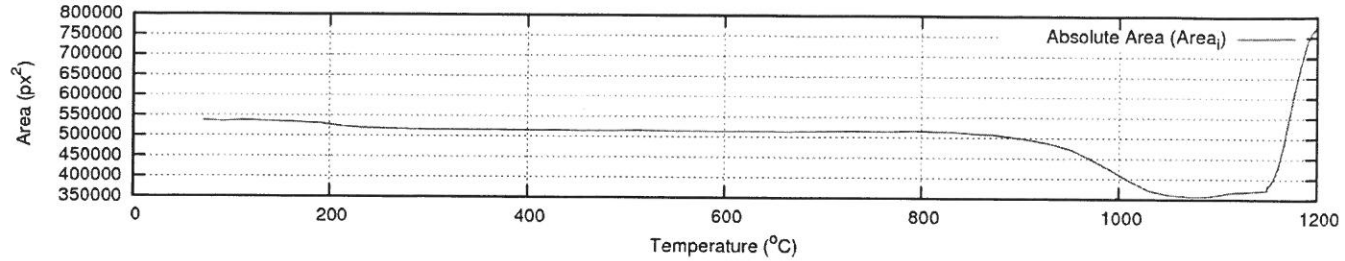
Images index	*Temperature*	*Images/min*
1 – 54	98 - 1150	0.5
54 – 336	1150 -1290	30

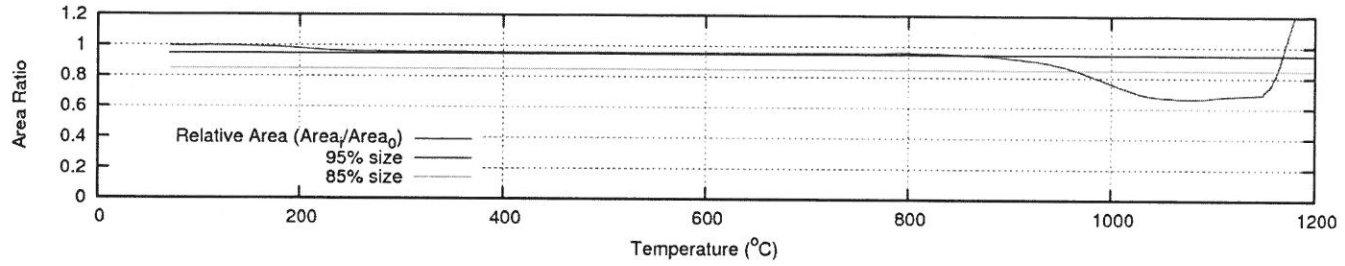
FIXED Table (according to times in Excel sheet)
Temperature increment: 10°C/min

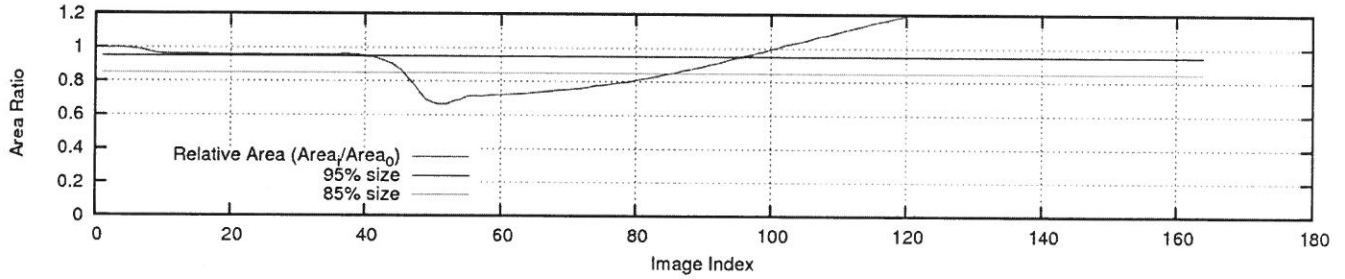
Images index	*Temperature*	*Images/min*
1 – 54	71 - 1149	0.5
54 – 369	1149 -1292	22.02



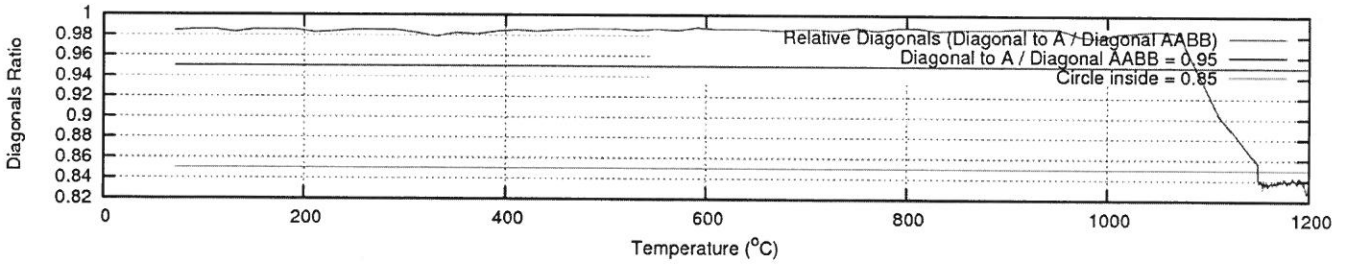
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Points: First Shrinkage and Maximum Shrinkage

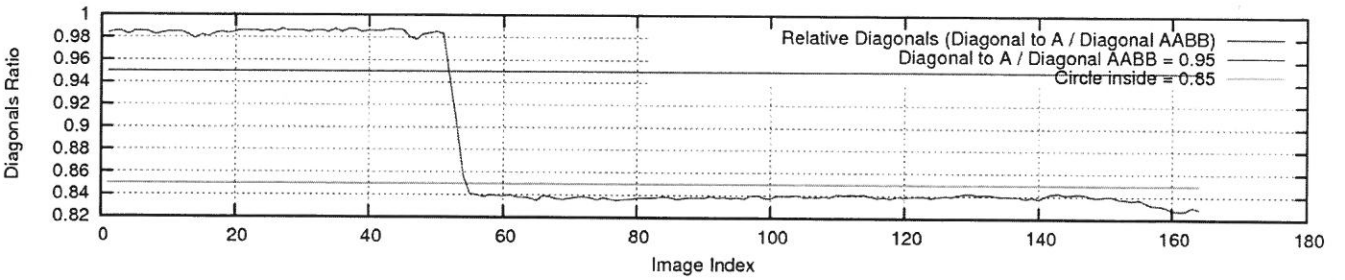


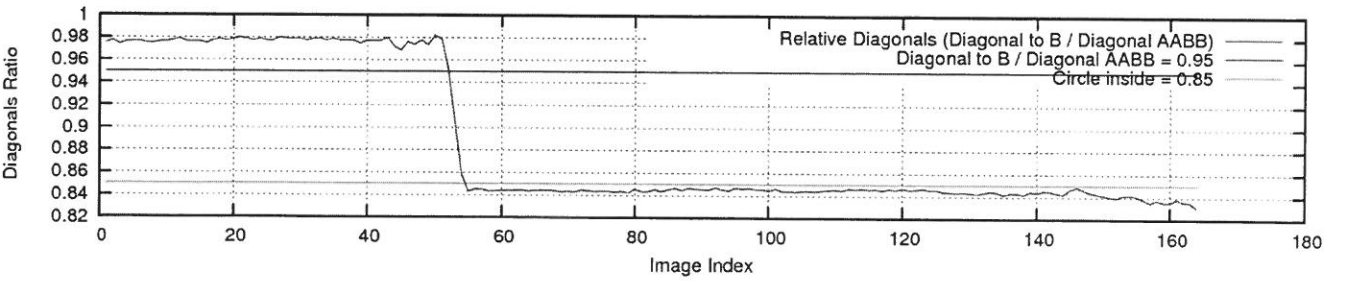




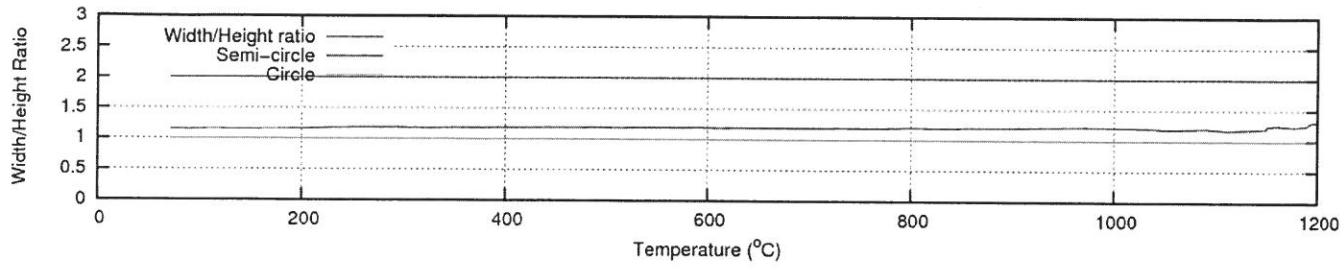
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening and Ball

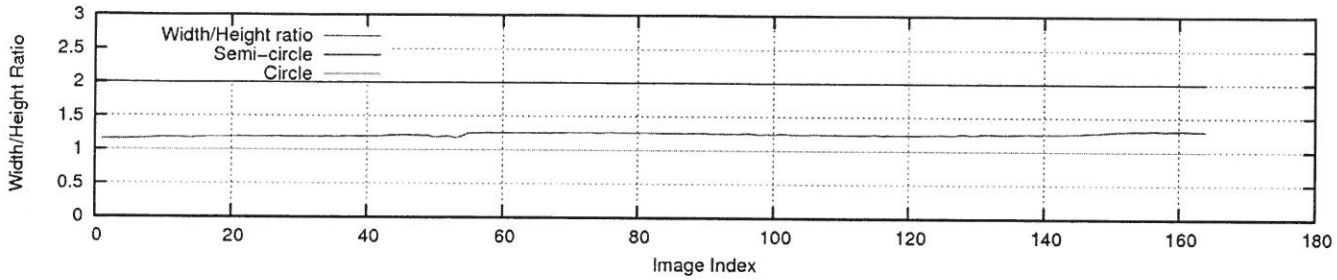


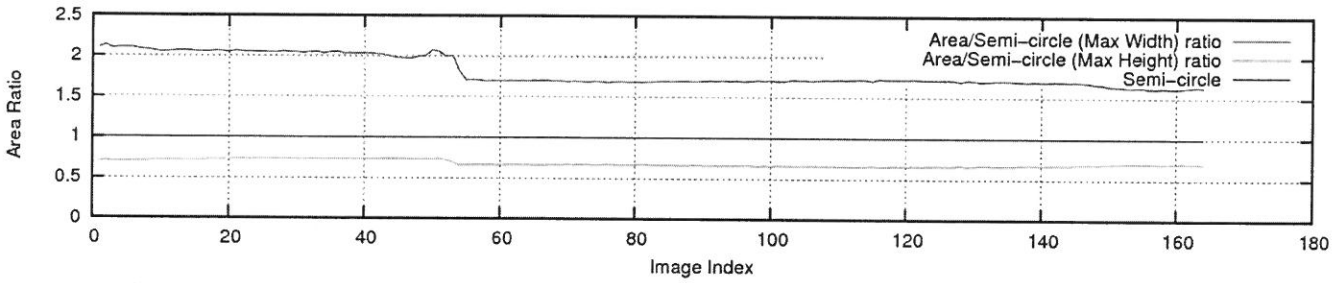




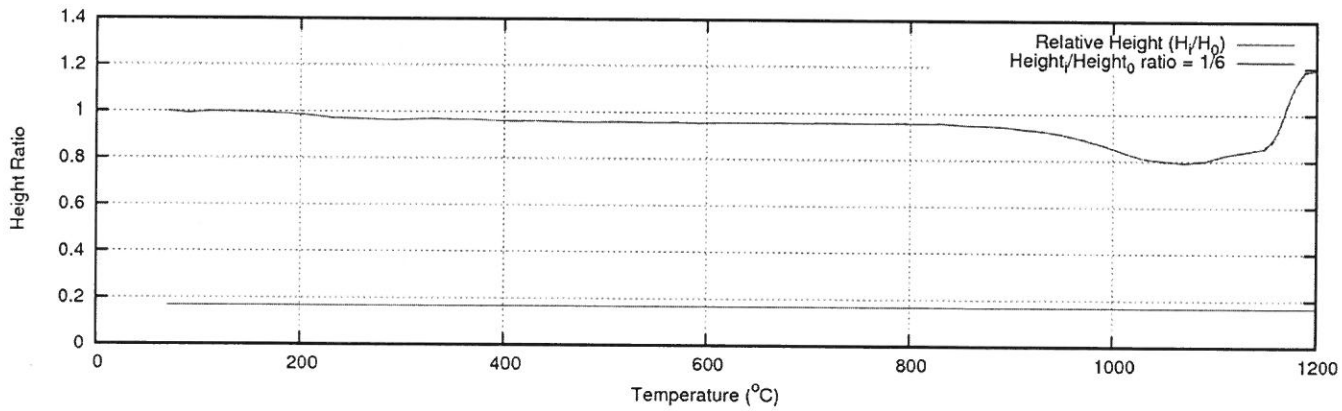
Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Half Ball

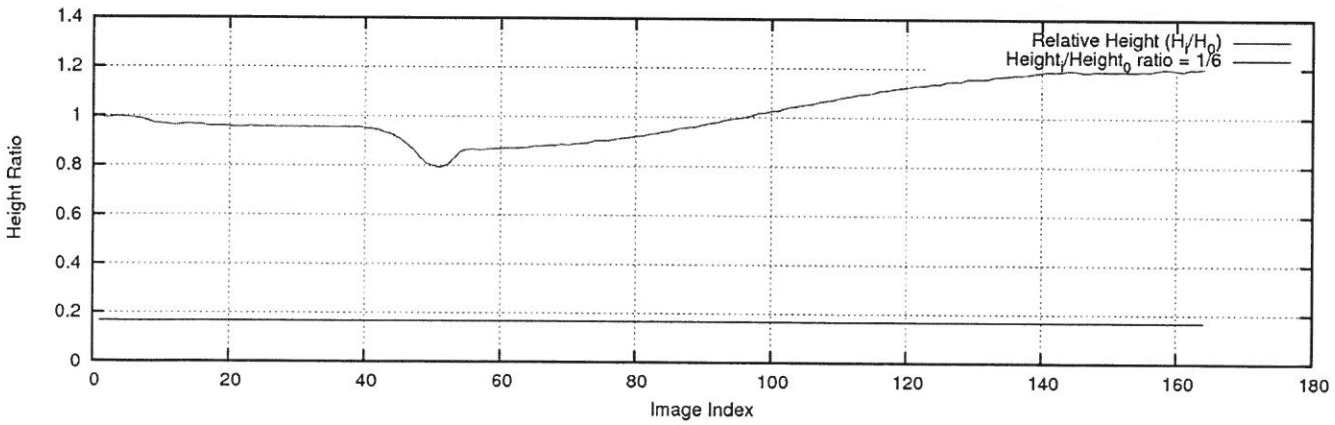






Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Flow





Hot Stage Microscopy Analysis Tool (HSMAT) – Notable Point: Softening (via Perimeter)