# The Air Pressure and Airflow Model of Aspirated Plosive [pha] and [tha] in Mandarin

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**Abstract:** Experimental analysis of Chinese aspirated plosive consonants is the basis analyze other kinds of consonants, and the plosive consonants preferably indicate the typical characteristics of consonants on the pronunciation mechanism and acoustic characteristics. Taking the plosive consonants as example, this paper took advantage of MATLAB programming and each consonant shall collected 100 syllables in total of 20 people (10 men and 10 women) as the experimental basis to establish the air pressure and airflow signal model through the sine function fitting, Gaussian function fitting, Cubic polynomial fitting, Fourier fitting and Exponential fitting of data in different intervals. It was concluded that the left part study area of the aspirated plosive [pha] air pressure signal was modeled by the sine function, and the right part study area of [pha] selection and airflow signals and all of [tha] were modeled by the Gaussian function.

## 1. Introduction

Breath is the "driving force" generated by speech. Without breath, there would be no speech. The study of air pressure and airflow changes during the generation of language is called phonetic aerodynamics [1]."The study of phonetic physiology has always been an important aspect of linguistics, because the study of speech physiological mechanism is the theoretical basis of phonetics."[2] In the pronunciation process of mandarin, air pressure plays a crucial role in the generation of pronunciation, and consonant analysis is the foundation. Understanding the characteristics of consonants in mandarin can provide some experience and reference for the speech acoustic analysis of a large number of Chinese dialects. In terms of application, in-depth experimental analysis results of consonants in mandarin can provide data for phonetic teaching, phonetic engineering, and the application of phonetic technology, etc., and act as support and reference for these studies [3].

In the 1980s, professor Fonte of the royal institute of technology in Sweden introduced the method to study pronunciation into China. Mr. Wu Zongji firstly conducted an experiment on the "distinguishing features of non-aspirated/aspirated consonants in mandarin", and believed that the air pressure of non-aspirated consonants was greater than that of aspirated ones [1]. Axu Hu studied the aerodynamics of the elastic vowels in Mongolian, and found that the airflow rate of the loose vowels was greater than that of the tense vowels, and the glottic resistance was less than that of the tense vowels [6] Yonghong Li (2015) conducted the aerodynamic study on initials consonants of Mandarin, and found that sound pressure, peak air pressure and airflow peak, and airflow parameters could be used as distinguishing features of consonant pronunciation methods [5].In this paper, by using MATLAB programming to preprocess and model the aspirated plosive air pressure signal collected by PAS6600, it lays a foundation for studying the pronunciation characteristics of consonants.

## 2. The speech signal acquisition

In this paper, the Phonatory aircraft System (PAS6600) of American KayPENTAX company is used to collect voice signals, which is composed of a mask with double handles, airflow mask, pressure sensor, test tube and microphone [4].The collected signal is stored in the default format. NSP format with a signal sampling rate of 22KHz.The voice signals collected by the system display four interfaces: voice signal, air flow signal, air pressure signal and three kinds of signal overlapping drawing, as shown in Fig.1.

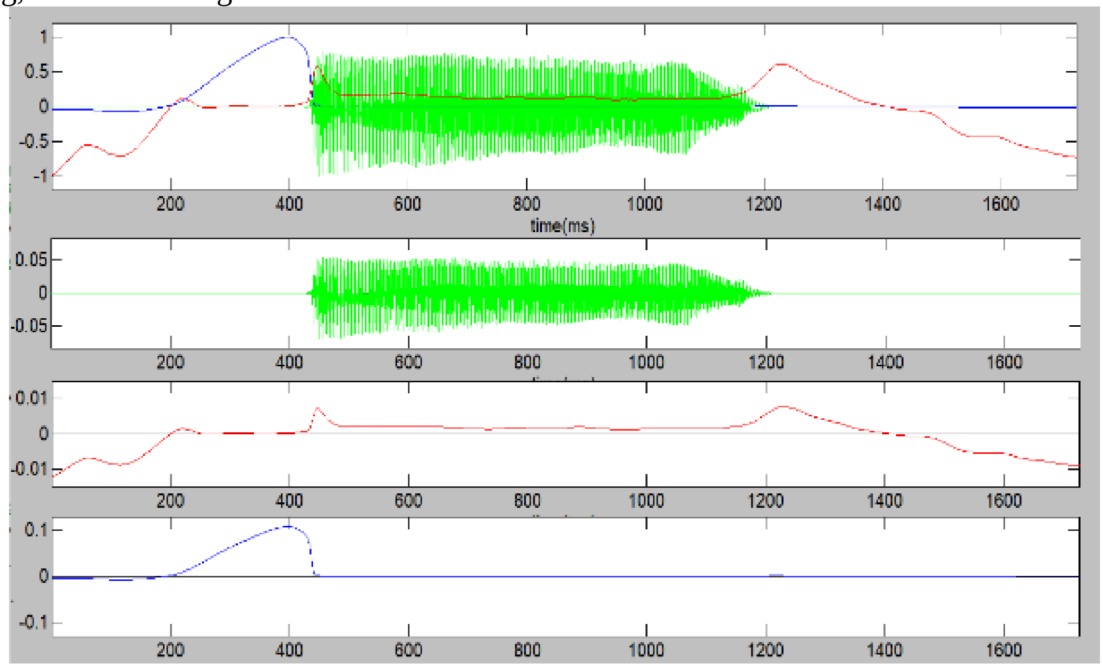


Figure 1. Respiratory signal analysis system diagram

## 3. Preprocessing of speech signals

The speech signal collected by the PAS6600 system is [pha] and [tha] repeated for 5 times, and the file is saved in the default. NSP, though MATLAB programming, the system default. NSP format file into. Wav file, easy to process the voice signal.

Cutting modethe, speech signals collected by MATLAB programming after the work is to extract the each speech signal pressure signal, after is the key cut signal the beginning and ending position, according to the studies of Chinese mandarin initials of aerodynamic Yonghong Li (2015), aspirated plosive before blasting into resistance and the resistance, the maximum pressure in the mouth; In the blasting stage, the lips suddenly open, the air pressure in the mouth plummets, and the air velocity rises rapidly from zero, forming transient noise. Ventilation stage: a large amount of air from the lungs directly from the mouth through the open glottis, and the air pressure rapidly drops to a lower value [5].So the syncopation starts at the point where the pressure signal is coming to an end and ends at the point where the airflow signal is flattening out.

## 4. Calculate the mean value of the signal curve

The pre-processed speech signal was programmed by MATLAB, taking the aspirated plosive [pha] and [tha] as an example, to overlay the air pressure signal. After the overlay, 3% signals of the upper, lower, left and right sides of the overlay were deleted to ensure higher stability of the data. According to the mean value of the points with different ordinates of the same abscissa, the mean curve of the air pressure signal is fitted, as shown in Fig.2 and Fig.3. The mean curve of the air flow signal is calculated as the same air pressure signal.

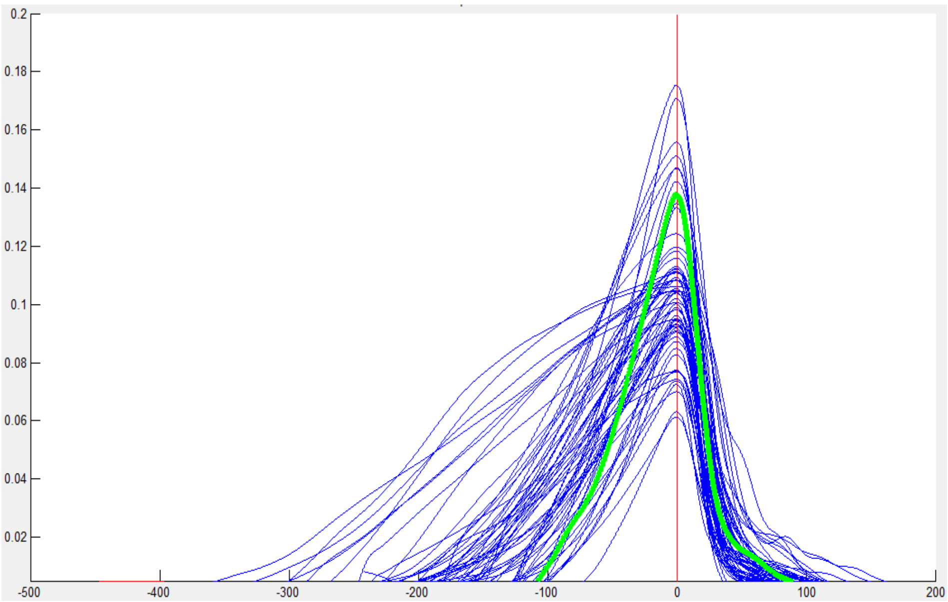


Figure 2. The Air pressure curve and mean curve of [pha]

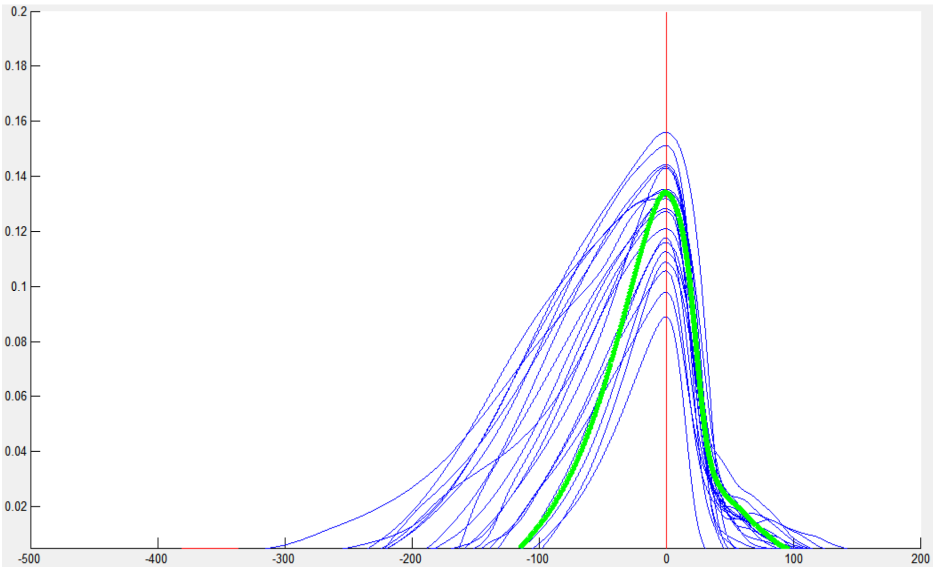


Figure 3. The Air pressure curve and mean curve of [tha]

## 5. Modeling of AIR pressure signals

### 5.1 Modeling of the aspirated plosive [pha] signal

In the aspirated plosive [pha] in air pressure signal, the data on both sides of the pressure signal has strong representative, with peaks as a dividing line, respectively for the two sides of the signal using the sine function fitting as shown in Fig. 4, and Gaussian function fitting as shown in Fig.5 analysis and establish the model equation 1, 2, 3, 4, and the SSE (variance) such as in 1, R-Square (determination coefficient) such as in 2, RMSE (root mean square) such as in 3 three common measure standard of selecting good function as the required model fitting effect.

$$\text{SSE} = \sum_{i=1}^{n} \omega i(yi - \hat{y}i)^{\wedge}2 \tag{1}$$

$$\text{R-square} = \frac{\sum_{i=1}^{n} wi(\hat{y}i - \bar{y})^2}{\sum_{i=1}^{n} wi(yi - \bar{y})^2} \tag{2}$$

$$RMSE = \sqrt{MSE} = \sqrt{\frac{SSE}{n}} = \sqrt{(1/n \sum_{i=1}^{n} wi(yi - \hat{y}i)^2)} \tag{3}$$

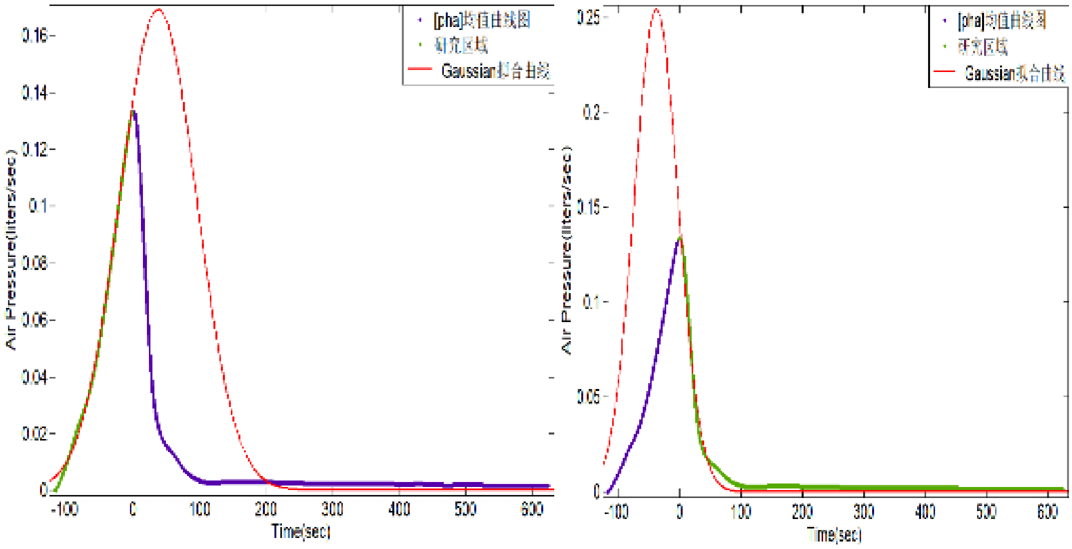


Figure 4. Gaussian (left, right)

$$Y11=0.1692*\exp(-((x-37.47)/81.92)^{\wedge}2) \quad (4)$$

$$Y12=0.2542*\exp(-((x+38.05)/50.82)^{\wedge}2) \quad (5)$$

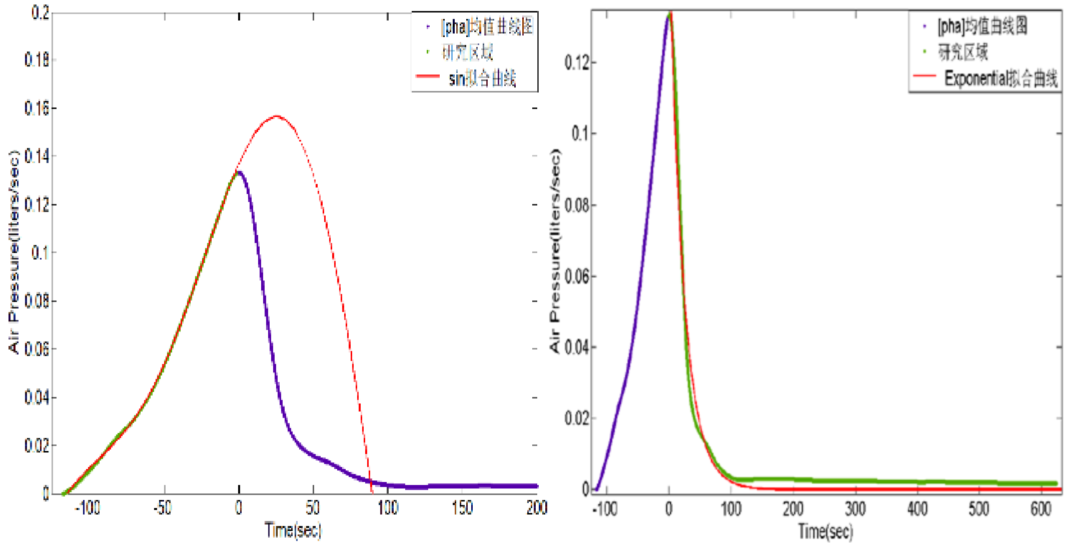


Figure 5. Sin, Exponential (left, right)

$$Y13=0.1494*\sin(0.01753*x+1.79)+0.06498*\sin(0.03079*x-0.1393) \quad (6)$$

$$Y14=0.1525*\exp(-0.04276*x) \quad (7)$$

### 5.2 Modeling of the aspirated plosive [tha] signal

The aspirated plosive [tha], as well as the signal is divided into two parts modeling analysis, because in this data, sine fitting effect is not ideal, adopt the Gaussian function fitting as shown in Fig.6, Fourier, an Exponential fitting as shown in Fig.7, such as equation 5,6,7,8 equation, and establish the model in SSE, R - square, RMSE as the basis of observation of fitting effect, choose the best fitting model.

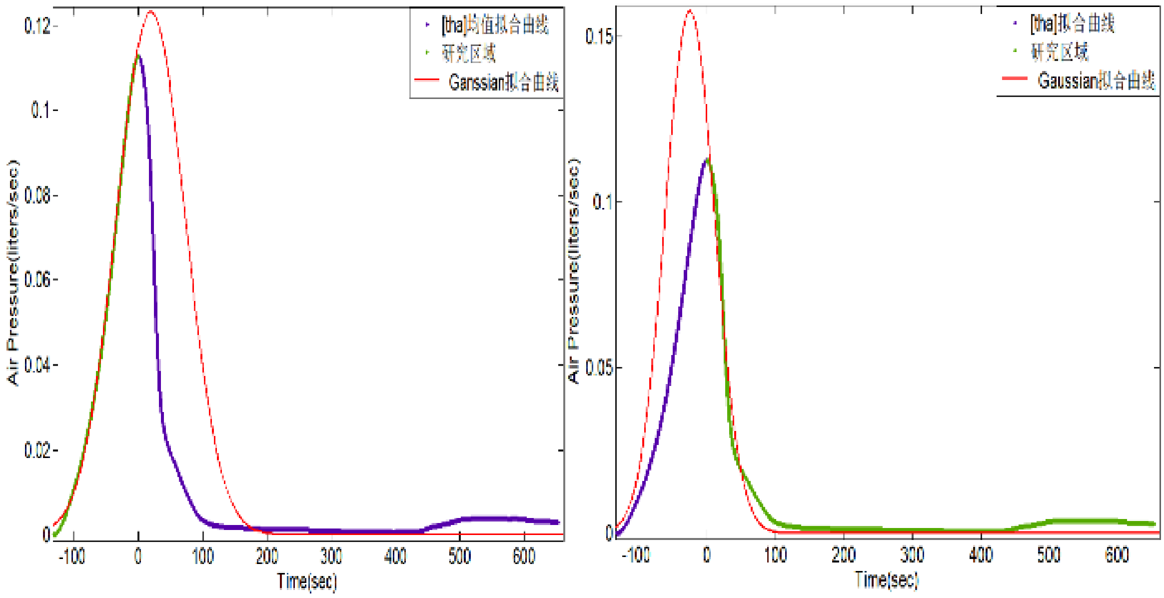


Figure 6. Gaussian (left, right)

Y21=0.1231*exp (-((x-19.68)/75.57) ^2) (8)

Y22=0.158*exp (-((x-24.69)/51.52) ^2) (9)

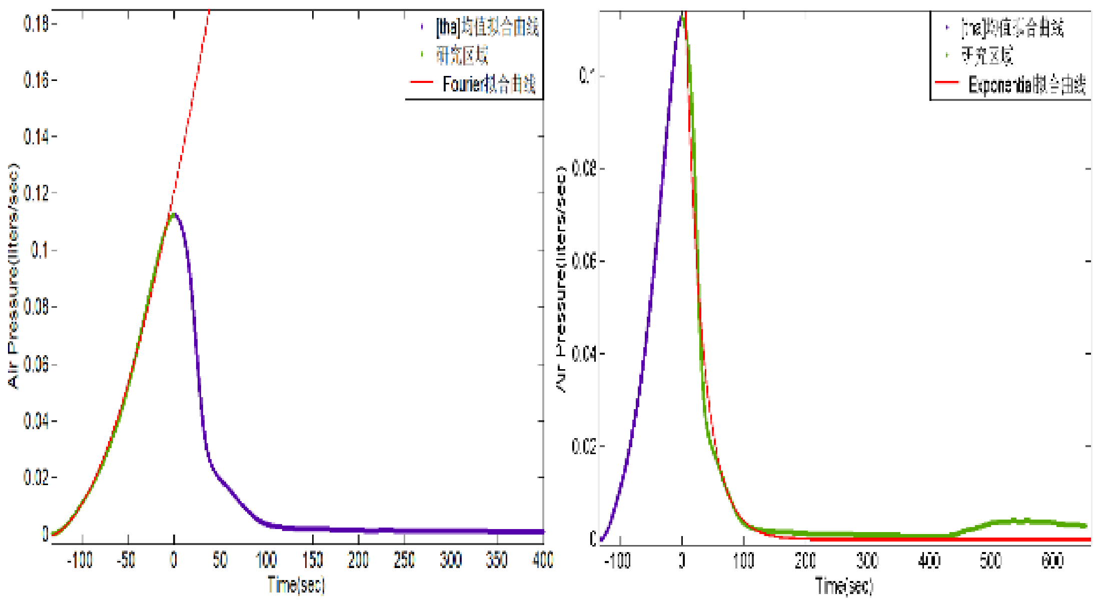


Figure 7. Fourier（left）Exponential（right）

Y23=0.2582-0.1374*cos(x*0.007) +0.2205*sin(x*0.007) (10)

Y24=0.1384*exp(-0.03537*x) (11)

## 6. Modeling of airflow signals

In the study of flow signal, to the plenum plosive [pha], [tha] signal modeling, the left hemisphere of the air flow signal more representative and the characteristic, based on the average curve, left side of the data signals are extracted, the air flow signal respectively using Gaussian, Cubic polynomial, an Exponential curve for fitting as shown in Fig.8, 9, and establish the model, such as equation 9,10,11,12.

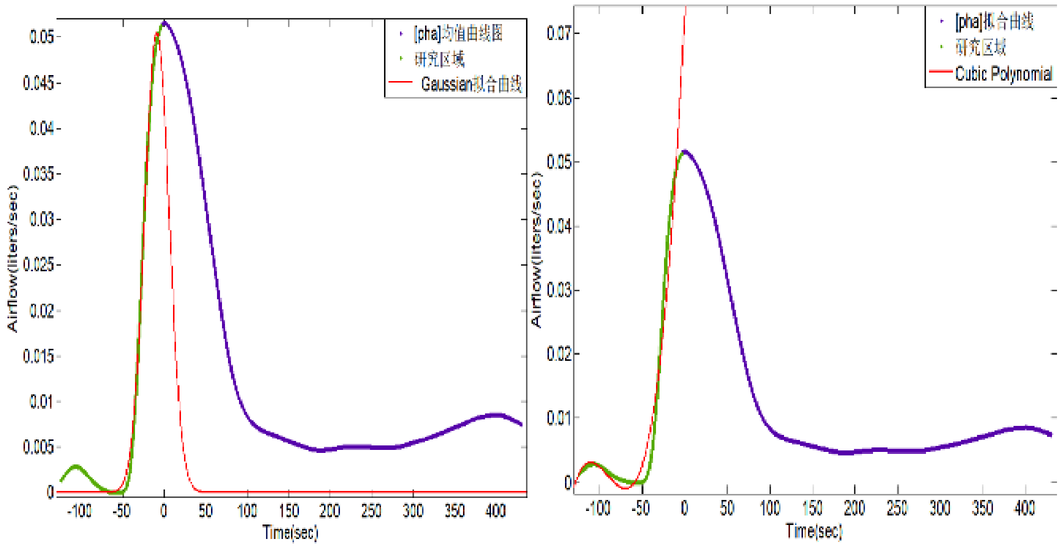


Figure 8. Gaussian (left) Cubic polynomial(right)

Y31=0.05049*exp (-((x+8.927)/20.7) ^2) (12)

Y32=1.178e-007*x^3+3.189e-005*x^2+0.07411 (13)

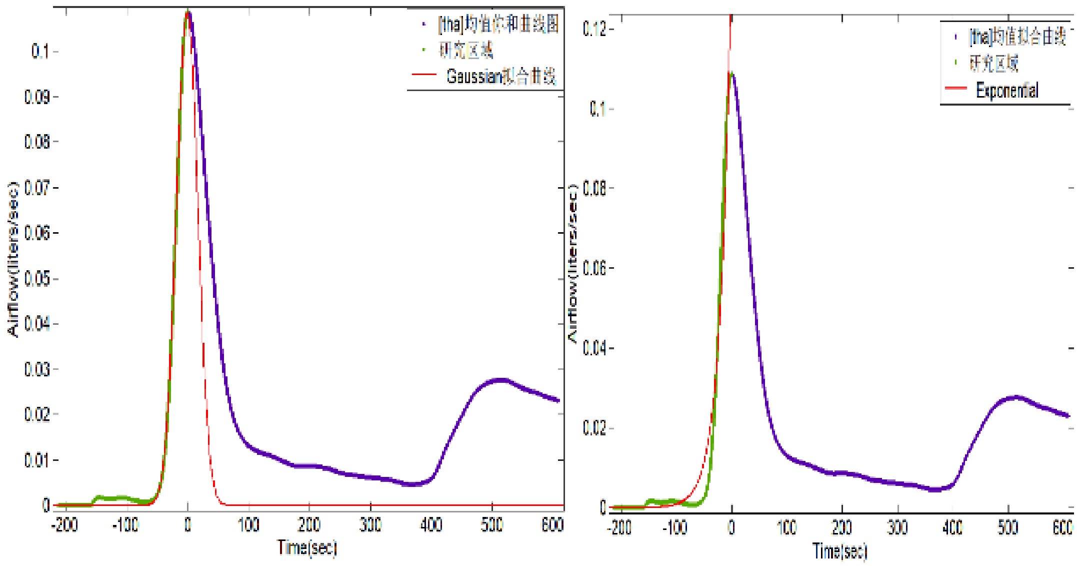


Fig. 9. Gaussian (left) Cubic polynomial (right)

Y31=0.1085*exp (-((x+1.302)/24.71) ^2) (14)

Y34=0.1381*exp (0.04997*x) (15)

## 7. Modeling ANALYSIS

By sine function fitting, Gaussian function fitting, Cubic polynomial fitting and Fourier fitting and an Exponential fitting, the aspirated plosive [pha] and [tha] air pressure signal modeling, SSE, R - Square, RMSE integrated as a measure of the fitting effect according to Table 1, the closer the SSE, RMSE 0, model selection and better fitting, data to predict the more successful; The normal value range of the R-Square "determination coefficient" is [0 1]. The closer it is to 1, the stronger the explanatory power of the equation variable to y is, the better the model selection and fitting effect is, and the more successful the data prediction is. According to the data show that the aspirated plosive [pha], air pressure signal model [tha] a better fitting effect of sine function fitting, but considering the practical equation, for the two signals right part of the study area, practical Gaussian, the error is relatively small, comprehensive conclusion aspirated plosive left part of the study area using the sine function modeling, the right part of the study area using the Gaussian function modeling.

Table.1. SSE RMSE and R-Square of two modeling methods:air pressure and airflow model of [pha] and [tha]

| Signal | Air Pressure | | | | Airflow | | valuation coefficient |
|---|---|---|---|---|---|---|---|
| | Left | | Right | | Left | | |
| Fitting | gaussian | sin | gaussian | exponential | gaussian | cubic | |
| [pha] | 0.0072 | 0.0011 | 0.139 | 0.1518 | 0.0064 | 0.026 | SSE |
| | 0.9983 | 0.9997 | 0.977 | 0.9748 | 0.9911 | 0.9639 | R-Square |
| | 0.0017 | 0.0007 | 0.0032 | 0.0033 | 0.0016 | 0.0031 | RMSE |
| Best Fitting | sin | | gaussian | | gaussian | | |
| Fitting | gaussian | fourier | gaussian | exponential | gaussian | exponential | |
| [tha] | 0.0044 | 0.0099 | 0.148 | 0.1576 | 0.0042 | 0.1372 | SSE |
| | 0.9992 | 0.9981 | 0.9724 | 0.9672 | 0.9988 | 0.9626 | R-Square |
| | 0.0011 | 0.0016 | 0.0032 | 0.0035 | 0.0095 | 0.0054 | RMSE |
| Best Fitting | gaussian | | gaussian | | gaussian | | |

## 8. Conclusion

This paper uses MATLAB programming to convert and preprocess the air pressure signal of the aspirated plosive [pha] and [tha]. By using each of the two good fitting effect functions to fit the signal, it takes SSE, R-Square and RMSE as the basis to observe the fitting effect and establish an appropriate model. Through the establishment of the model, it is concluded that the air pressure signal can be used as the distinguishing characteristics of t aspirated plosive, and the further understanding of aspirated plosive has laid a good foundation for the study of aerodynamics in mandarin.


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