



Acoustic Study of Vibrato in “Hezhou Hua’er”

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Abstract. This paper takes vibrato in “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” sung by Mr. Zhu Zhonglu as the research subject, and the parameters of the vibrato such as duration, pitch, intensity and sound quality are studied. From the perspective of duration, the vibrato in Hezhou Hua’er is long or short, which depends on the emotional needs of singing, and also requires the singer to master the singing breath well. From the point of view of the fundamental frequency, the pitch of this song is higher, so that the listener can feel the characteristics of the folk song of the Northwest Plateau; From the perspective of sound intensity, the amplitude product data well interpreted the energy variation of vibrato in Hezhou Hua’er. According to the long-term average power spectrum, there is singer formant in Hezhou Hua’er singing. On the one hand, the internal mechanism of acoustics and physiology of vibrato is explained by computer quantitative research method, On the other hand, this paper attempts to establish the basis for establishing a scientific and standardized digital protection standard of oral culture.

Keywords: vibrato · Duration · Fundamental frequency · The intensity of sound · Spectrum

1 Introduction

“Hua’er” is popular in Gansu, Qinghai, Ningxia, Shanxi, Xinjiang and other places in the northwest of China. It is a folk song with strong local color, rich emotions, and unique rhythm and singing style. From the history of “Hua’er”, it is a folk love song, and later it gradually involves other life contents. It can be divided into two schools: “Hezhou Hua’er” and “Taomin Hua’er”. “Taomin Hua’er” is mainly created and sung by the Han people. There are few tunes, and the singing mainly adopts collective duet; “Hua’er” is mainly created and sung by Tibetan, Dongxiang, Hui and other minorities. It has rich music and flexible singing forms. It is a folk song sung in Chinese by many nationalities living in the vast northwest land. In 2006, “Hua’er” was listed in the first batch of intangible cultural heritage in China, and in 2009 it was selected into the Representative List of the Intangible Cultural Heritage of Humanity of the United Nations [5].

“Hua’er” is a kind of folk art. The reason why it has a unique color different from other folk songs is that language is one of its important components. It uses colloquial literary

language, which is simple, natural and full of life atmosphere. It uses whitestrokes, metaphor, exaggeration, reduplication and other ways to build images, which is easy to be understood and loved by the people.

“Hua’er” has a unique musical tune and singing mode. It is equipped with a large number of interlining words and interlining sentences in singing. The tones are mostly high, long and loud, and the jumping range is large. The “Hezhou Hua’er” music has a wide a wide vocal range, and there are mainly three singing methods: “Jian Yin” singing (singing with falsetto), “Cang yin” singing (singing with real voice), and “Jian Cang yin” singing (singing with real voice and falsetto) [8].

There are many kinds of songs of “Hezhou Hua’er”, of which only about thirty kinds are the most popular. “Primary Song of Hezhou” sung by Mr.Zhu Zhonglu is one of the most basic and popular main tunes in this paper. Because its tune is the most rich in the characteristics of the northwest plateau folk songs like the “Hezhou Hua’er”, such as its high pitched, wide range, and fluctuating melodies, its popularity and influence are great, and it is known as the “King of Hua’er Songs”. It belongs to the “Long tune”. Its tone is euphemistic and lingering, with sad emotion, wide vocal range, interlining words [2, 3].

Vibrato is a unique technique in singing of Hua’er. When singing vibrato, we should control the tightness of vocal cords and the coordination of breath to make singing distinctive, fresh and vivid. The vibrato in singing of Hua’er is close to that in Mongolian long tune, and is mainly used to sing decorative melody and melody with long duration. There are short vibrato and long vibrato in singing of Hua’er. Short vibrato is short in duration, and the vibration frequency varies from fast to slow as the singer’s mood changes. Long vibrato time value is longer, so that long sound rich change, sound vast, distant, full of dynamic [9].

2 Research Method

As a kind of analog signal carrying specific information, voice has become an important means to acquire information and disseminate information. Voice signal is the most direct signal of oral culture, and also the most intuitive signal in human perception. It is the most extensive protection and inheritance method for a long time.

2.1 Informant

This paper selects the song “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)”, which was sung by Mr. Zhu Zhonglu in the CD album “King of Hua’er in Northwest China - Zhu Zhonglu” published by China Records Corporation and released by China Records Shanghai Company in 2006.

Zhu Zhonglu, born in Tongren County, Qinghai Province in 1922, is a Hua’er singing artist, known as the “King of Hua’er”. He started to learn singing Hua’er since childhood, learn from others, and form his own singing style. The voice is bright and straight, strong and soft, with authentic charm. The singing voice has strong mountain flavor, giving people a plateau feeling of sky high and bright air [10].

2.2 Phonetic Parameters

From the perspective of acoustics, the artistic characteristics of oral culture in rhythm can be quantitatively studied through the parameters such as duration, pitch, intensity and sound quality.

In this paper, Praat and Wavesufer software are used for voice signal analysis to extract parameters such as duration, fundamental frequency, sound intensity and long-term average power spectrum.

3 Duration Analysis

The duration is the duration of the tone. The time length of each vibrato during singing can be extracted, which mainly reflects the performance of the rhythm in time, generally in seconds (s) or milliseconds (ms) as the unit. It should be noted that the starting point and ending point should be marked accurately.

Taking “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” as an example, 49 vibrato segments are obtained in the whole song according to the phonology units of the lyrics. The results are shown in Fig. 1 after normalization of the extracted vibrato duration.

According to the experimental results, the average duration of vibrato in “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” is 1.391m, and the longest duration of vibrato is 5.144m.

It can be seen from Fig. 1 that according to the duration of the segment, it can be divided into two groups: 11 long vibrato and 38 short vibrato, among which the long vibrato are basically the trailing voice at the end. The vibrato with the longest duration is 3.6 times longer than the vibrato with the shortest duration. It can be seen that the control of breath is very important in singing of Hezhou Hua’er, which requires for the singer to control the breath well.

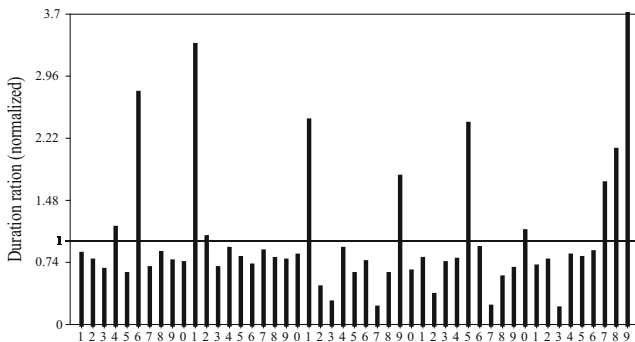


Fig. 1. Vibrato duration ratio of Primary Song of Hezhou

4 Fundamental Frequency Analysis

The fundamental frequency of speech is completely different from that of singing Hua’er. The fundamental frequency of artistic voice is often higher than that of ordinary speech. This is closely related to the emotion released by the singer in singing. Low frequency tunes give people a deep, thick and rough feeling; High frequency tunes give people a bright and sharp feeling. Physiologically, it is reflected in the speed of vocal cord vibration, and the unit of fundamental frequency is Hz. Generally speaking, tightening and thinning of the vocal folds increases pitch, whereas loosening of the vocal folds decreases pitch. That is, how high or low the melody of a tune is perceived by humans [4]. The change of the fundamental frequency curve can reflect certain characteristics of the music style.

Male voice has a narrow range of fundamental frequency distribution between 200Hz and 500Hz, with an average fundamental frequency of about 350Hz, while female voice has a relatively wide range of fundamental frequency distribution between 200Hz and 600Hz, with an average fundamental frequency of about 410Hz. The fundamental frequency of the song “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” sung by Mr. Zhu Zhonglu ranges from 200Hz to 600Hz, which also shows that Hezhou Hua’er has formed their own distinctive singing voice and singing skills in the long-term singing.

Vibrato is a kind of embellient method widely used in Hezhou Hua’er. When the vibrato is issued, the air flow will be fast and slow alternately, the vocal cords will be rhythmically fast and slow, and the throat muscles will beat violently. Figure 2 shows the fundamental frequency change diagram of the long vibrato in Mr. Zhu Zhonglu’s singing “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)”.

The fundamental frequency of the vibrato in Fig. 2 changes up and down in a wavy manner over time. The upper limit value of the fundamental frequency of the vibrato is 475Hz, and the lower limit value is 427Hz. It is reset every 320ms or so. We call it the periodicity of the fundamental frequency change or the vibrato unit. One vibrato unit is about 320ms, and the variation amplitude is about 30Hz. The average fundamental frequency of the vibrato is calculated at 450Hz, which means that the vibration period

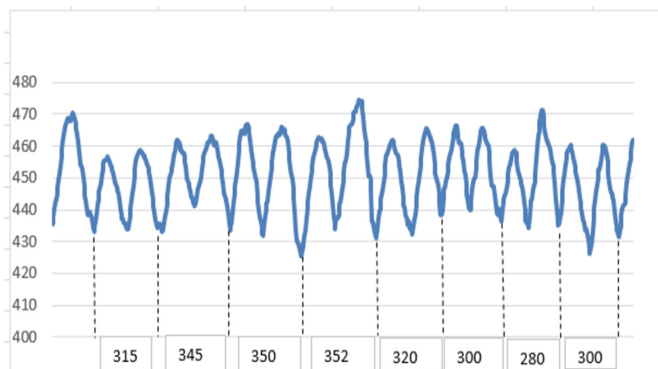


Fig. 2. The periodic variation of the fundamental frequency of vibrato

of the vocal cords is 2ms. In a vibrato unit, the vocal cord vibrates for 160 cycles (320ms/2ms), and the change of fundamental frequency of each cycle is about 5Hz, that is, the time of continuous cycles increases or decreases by about 5ms. This also reflects the micro way in which human beings control vocal folds.

5 Sound Intensity Analysis

Sound intensity refers to the strength of sound. We feel the energy of sound and hear the light and heavy of sound. It mainly includes two factors, namely the amplitude of vocal fold vibration and the intensity of the resonance of the vocal tract to the sound source during singing. The air flow in the lungs directly affects the amplitude of vocal fold vibration. In general, if the air velocity is fast and the air flow is large, the amplitude of the vocal cords will be large, and the energy of the sound source will be large. In vocal music, the control of the strength of each tone, each group of tones or each phrase is the strength, which is also colloquially known as the volume. The change of the energy curve can also reflect certain characteristics of music style.

The change of sound intensity is one of the important factors of vocal music performance. Any kind of melody with strong expressive force often has rich and delicate strength changes. In this paper, the amplitude product, a new speech parameter introduced by Liang Lei and Shi Feng (2010), is used to study the change of sound intensity in Hezhou Hua'er.

The so-called amplitude product refers to "the sum of the amplitudes of each sampling point in the selected voice segment". The amplitude product of a certain segment of voice = average amplitude * duration [6].

The sound intensity value obtained through the amplitude product is the area value of the sound intensity in a period of time, which is more consistent with the specific acoustic performance of sound intensity. The intensity of voice should be measured by the intensity of the overall voice vibration over a period of time.

The average amplitude product of 49 vibrato segments "Climb up the high mountain to oversee the plain (Primary Song of Hezhou)" sung by Mr. Zhu Zhonglu is 3432md, and the maximum is 8908md. And normalize the extracted the amplitude products of long and short vibrato, and the results are shown in Fig. 3.

The song "Climb up the high mountain to oversee the plain (Primary Song of Hezhou)", which was sung by Mr. Zhu Zhonglu, is loud and long tone, undulating rhythm changes and the frequent occurrence of high pitched prolonged tremors, which is a good interpretation from the above data. According to the needs of expression and emotion during singing, the energy of the voice is strong or weak. For example, some decorative interlining words have shorter singing time, but the amplitude product is larger than that of some decorative interlining words with longer singing time. This shows that the singing rhythm has a large fluctuation, which can fully display the characteristics of the passionate and bold singing of Hezhou Hua'er.

Taking the energy change of vibrato as an example, the above figure in Fig. 4 shows the voice waveform of the selected decorative word "ah", and the following figure shows the three-dimensional spectrogram and energy change curve of the decorative word "ah".

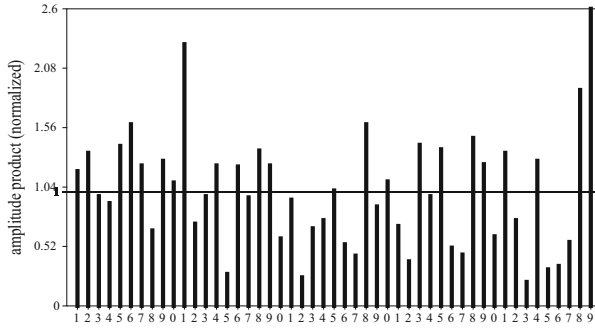


Fig. 3. The amplitude product of vibrato --Primary Song of Hezhou

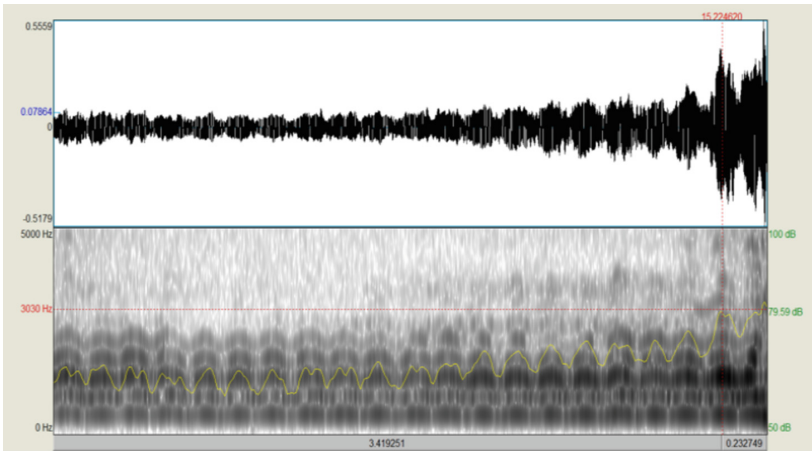


Fig. 4. Decorative interlining words “ah”

On the whole, the energy of vibrato gradually becomes stronger from weak, and changes periodically, similar to the fundamental frequency of vibrato. After measurement, the average duration of each energy cycle of vibrato is between 230ms and 270ms, and the amplitude change from the peak value to the valley value of the middle stationary cycle is about 5dB, that is, the energy fluctuation of the stable vibrato energy within 250ms is about 5dB. The minimum value of the peak amplitude is 59dB, and the maximum value is about 79dB, which means that there is about 20dB increase from the beginning of vibrato to the climax.

According to the analysis results in Part V, the vibrato samples are classified into four types of energy modes: smiling type (Fig. 5), arch type (Fig. 6), climbing type (Fig. 7) and gliding type (Fig. 8). Among them, the smiling and arch type are the most energy modes, and most of them are long vibrato; the climbing and gliding type energy modes are mostly short vibrato. This shows that Hezhou Hua’er have strong expressive power, and their melody changes are rich and delicate, which fully shows the features of the Northwest plateau.

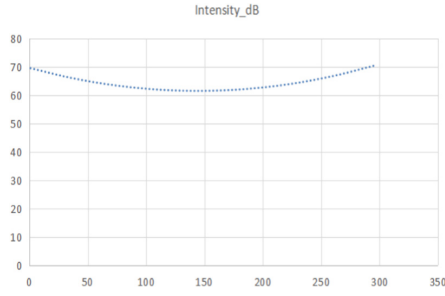


Fig. 5. Smiling type

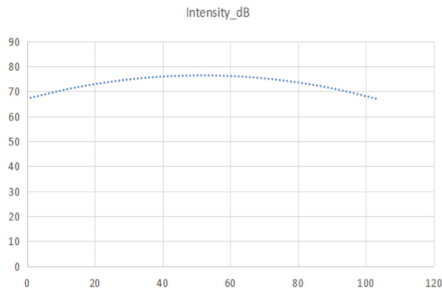


Fig. 6. Arch type

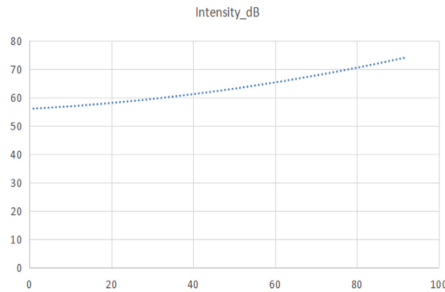


Fig. 7. Climbing type

6 Spectrum Analysis

Broadly speaking, sound quality is generally subjectively assessed through variations and combinations of loudness, pitch, and pleasantness. The narrow sense of sound quality mainly refers to the energy distribution of different frequency bands, that is, the spectrum.

In spectrum analysis, the method of calculating Long-term average spectra (LTAS) is often used in the study of continuous speech and singing. LTAS averages the spectrum data over a period of time and can present all the spectral characteristics of a sound, which tends to be stable after the duration reaches 30-40s. The shape of LTAS reflects the characteristics of both the source and the resonance, which can highlight the relatively

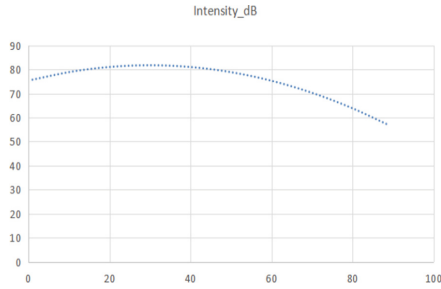


Fig. 8. Gliding type

stable spectral characteristics [7]. From the resonance characteristics, resonance is a very important factor in singing, and it is also an important means of expression in singing art, which can make people’s voice become clear, bright and more penetrating. Professor Sundberg proposed that in bel Conto, bass, baritone, tenor and mezzo-soprano show a significant peak between 2500-3300Hz of LTAS, which is called singer formant. In many researches on singing, there is the concept of singing formant, and it is believed that there is a relatively high-energy resonance region around the frequency of 2400-3200Hz, which contributes more to the voice quality. In this paper, a singing passage in “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” is selected to calculate the long-term average power spectrum, as shown in Fig. 9.

From above the Fig. 9, we can see that the change form of LTAS curve about this song. There is a main peak in the LTAS curve between 600-800Hz, and the slope of the decline after the main peak is relatively large. There is a significant peak between 2800-3200Hz, which we think is the singer resonance peak, that is to say, there is a singer resonance peak in the singing of Hezhou Hua’er.

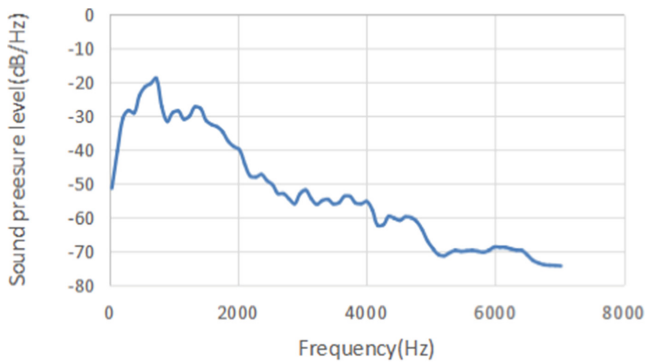


Fig. 9. Long-term-average spectra

7 Conclusion

This paper makes a quantitative study and analysis of the vibrato in “Climb up the high mountain to oversee the plain (Primary Song of Hezhou)” sung by Mr. Zhu Zhonglu through four acoustic parameters: duration, energy, fundamental frequency and Long-term-average spectra, which intuitively shows the acoustic characteristics of the vibrato in Hezhou Hua’er. This paper makes a preliminary analysis of the singing method of Hua’er by using acoustic methods in order to further study it.

At present, the inheritance and protection of oral culture is in an active exploration stage, and it is not yet possible to fully establish a standard, normative and unified digital protection methods, and it needs in-depth research in many aspects. However, with the continuous progress of research technology, we can constantly promote the deepening of protection methods, and constantly expand the connotation and extension of protection [1].

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