A Study of Creative Engineering Education by Making Musical Instruments

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Abstract

Recently a number of students who do not like science and technology increase, in not only Japan but also many of advanced countries. Therefore, lower grade students are poor ability of engineering design. The development of an attractive teaching material for the student in engineering course is required. We propose the woodwork violin making as a teaching material.
Students can learn the concept of manufacturing product which consists of material, structure and process.
Since musical instruments are made from wood, the advantages are, (1) student can make it at short time, (2) their tones can be evaluated by sensual and technological method. In addition, students can understand measurement technique and technological evaluation method of tones. This paper shows that violin making is excellent teaching material, and it will contribute to creative education.

Introduction

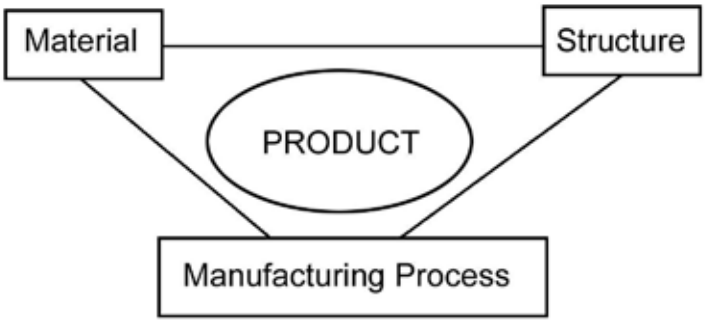
Most of students design several system with mechanical parts as the graduation research in university or technical college. The graduation research includes all process of structural design, (planning, design, production, and evaluation). The higher grade students are able to make experience about all process through their college curriculum[1].
On the other hand, recently a number of students who do not like science and technology increase, in not only Japan but also many of advanced countries. Therefore, it is necessary for lower grade students with poor experience of machine design skill to make experience of total design process for engineering. Total education for design practice trains the basic ability and creativity of mechanical engineering.
Many effective education programs have been developed. However, all colleges can not use the same program, because of different practical environment, for example, equipment, machine tools, and so on. Therefore, it is important to develop the excellent education program that do not depend on their equipments or practice environments. In recent years, there are many students who have no experiences of design and technological making before entrance of college or university.
In order to skill up this engineering design ability, metal materials are usually used at the practice or lecture in the university and technical college. However, it takes a long time for working and needs higher skill for student. This paper propose the wooden musical instrument making as a hands-on teaching. Wood materials can be worked easily for freshmen, and students have already experienced woodwork in junior high school. Using wood can make up a system with several elements in short time.
Student makes violin, and they experience product design, process design, actual produce and its performance evaluation. The violin making is most attractive theme for student's interest. Because, it is a traditional hand-craft product, and is rare as an object of engineering.

Educational issue and target

"Product" targeted in engineering education has material and structure as shown in Fig.1. Also, the product has manufacturing process as another element. Determination of manufacturing process gives most important function to product as same as structure and material. It is necessary to teach the interrelation of the elements of product at early stage of engineering education. Then, we developed the education program for students to understand the structural element's role through violin making.

Considering violin as an artificial product, it has unique shape and structure of musical instruments. As function of musical instrument, good tone is required. There are various materials for musical instrument now, though violin is traditionally made from wood. Students can select material from many kinds of wood. In addition, the tone of the produced violin can be evaluated using computer as the function of the product. The violin making is the superior subject as a total engineering design process in basic engineering education.

Fig.1 The relationship between material, structure and manufacturing process of product



Subject for practice

Structure of violin

There are no industrial standard for violin. The tone of each violin depends on material, shape, and technique of craftsman. Many craftsmen have been making violin as art craft for professional player. On the other hand many maker fabricate it using computer aided machine tool. Craftsmen use not only many standard tools but also special tools made by himself. Furthermore, the making processes are very different by each craftsman. Different process of each craftsman's technique makes the differences of the performance of violin.

Fig.2 shows the inner structure of violin cut from 3D-CAD model. The most important parts, as a medium for transmitting vibration of sound, are bridge, top and back plate, bass bar and sound post. This hands-on practice is violin making with different material and shape. Students made six kinds of violin with different material and shape, as shown in Table 1. Five

Fig.2 The inner structure of violin

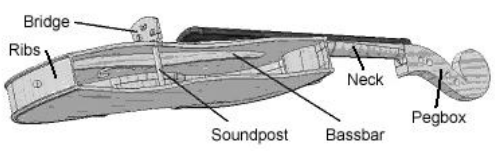


Fig.3°°Violin made by Paulownia

violins with flat shape of top plate and back plate are made of Paulownia, Agathis, Japanese

Table1 The specification of violins

Model No.	Material of plate	Thickness of board [mm]	f hole on top plate	Shape of body
1	Paulownia	5	with	Flat
2	Agathis	3	with	Flat
3	Japanese cypress	3	with	Flat
4	Veneer	5	with	Flat
5	Veneer	5	without	Flat
6	Japanese cedar	2.5-3.8	with	Arched

Cypress and Veneer. Among them, flat top plate with and without f-hole are prepared for comparison with shapes, and arch shaped top and back plate is imitated from ordinary violin.

Comparison of materials

For easy producing, student designed a simple model of violin. Three violins were made of different kinds of wood with same shape shown in Fig.3. The specification is shown in Table 2. The time required to make the violin is shown in Table 3. Each top and back plate was cut with a laser beam machine. Therefore, the same shaped plates were produced in short time.

Table 2 The parts of violin and processing methods

Parts	Material	Processing method	Educational technology
Top and Back plate	Paulownia Japanese cypress Agathis	LASER beam Machine	NC programming Theory of LASER
Ribs	Balsa (t=1mm)	Knife	How to use the knife
Neck	Japanese cedar	Gouge Drilling machine	Hoe to use tools and machine tools
Bridge	Agathis (t=3mm)	LASER beam Machine	
Peg	Plastics	Marketed product	
Tailpiece	Plastics		

Table 3 Process time for each process

Parts	Operation	Operation time[h]	Necessary days
Top plate	NC programming	25	
Back plate	LASER beam machining	1	
Neck	Cutting with Gouge	20	
Fabrication	Adhesion	14	3days

Total time was 60 hours, and about 25 hours was taken for programming of NC data for the laser beam machine of cutting top and back plate and bridge. By using router machine, it takes short time to make the peg box on neck. But in this practice, students use woodworking gouge to learn the wood craft skill. Other parts were bought from shop.

Comparison of the body shape

Next, to compare tone affected by different body shape, the students made violin as same shape as one made by maker. It was same size and shape but material of top and back plate was Japanese cedar board. Japanese cedar board is easy to obtain in Japan and easy to cut.

They learn a traditional method of making violin, and how to use the special tools for violin making. They can make

the violin body referring to the text [2]-[4]. Fig.4 shows the process of violin making. They got much guidance from craftsman about uncertain points.

Fig. 4 Main process of making violin

Transfer shape and make guides the violin top plate

Cut out the top plate from wood board

Carve plate according with guide

Plane the surface of top by using violin plane

Measure the thickness plate

Glued and clumped Ribs, the top and back plate

Evaluation of tone of the violin

Evaluation of instrument is very complex and difficult. The most important evaluation point is a tone. However, the sound of musical instrument has been evaluated by person's sensory, because of difficulty of quantitative evaluation.

Fig.5 Violins with different shapes

(a) Made by Japanese cedar with arched both plates

(b) Without *f*-hole on top plate

(c) With *f*-hole on top plate

In this practice, frequency response of the violin tone was analyzed as a quantitative analysis method[5]. The reason of using frequency response for evaluating the tone are as follows;

1. The frequency analysis on the tone of musical instruments is used as general evaluation method.
2. Frequency analysis is an indispensable subject on engineering education as a typical application of signal processing.
3. FFT is effective educational tool to understand wave analysis.

Result of tone evaluation on FFT analysis

One of the methods for tone evaluation is formant analysis that uses the estimation of the overall shape of the spectrum amplitude envelope[6]. Musical instruments sound complex tones consisting of the fundamental frequency and a combination of harmonic frequencies. Then measuring system shown in Fig.6 is consist of PC, audio capture (A/D converter), microphone and FFT analyzer.

Fig.6 The experimental apparatus

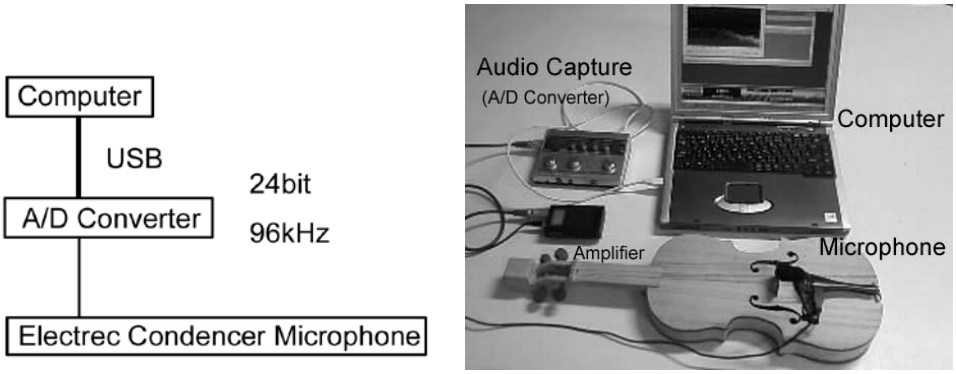


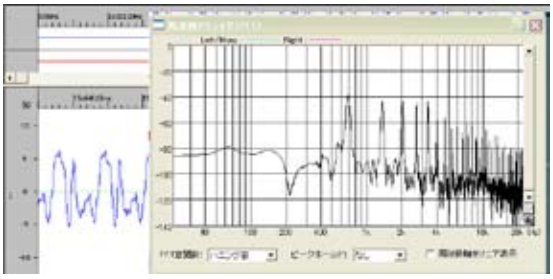
Fig. 7 shows the shape of waves and the frequency analysis of each violin tone of open E string. Its frequency is 660Hz. The FFT result at violin of handmade by craftsman has higher harmonics of 660Hz. The tone of violins made of Japanese cypress and Paulownia is better than others. The tone of violin made of Japanese cedar with arched shapes of plates is much better than others[7].

Educational effect

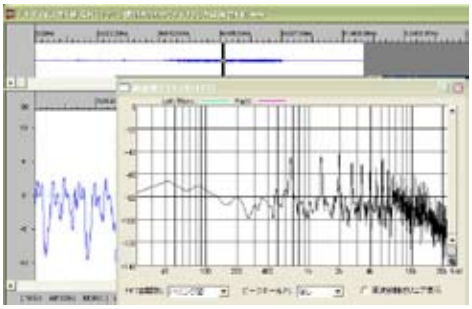
Because metal processing is popular exercise in college, woodwork may not be suitable for the technical college student. However, almost students have a few experience of woodwork on their junior high school. Many students are lack of training for using even woodwork tools as for hand plane and gouge. Therefore, advanced education material of the woodwork is significant.

It is not so long time to make practice on woodwork. Specially, the violin making is suitable for teaching subject how to use tools and how to use the evaluation method of frequency analysis. In this paper, creative engineering education program by making musical instruments was proposed. The results are summarized as follows;

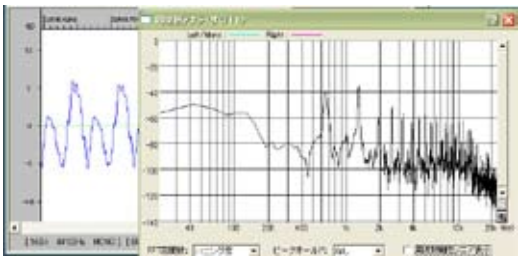
Fig.7 The result of frequency response characteristic playing E strings



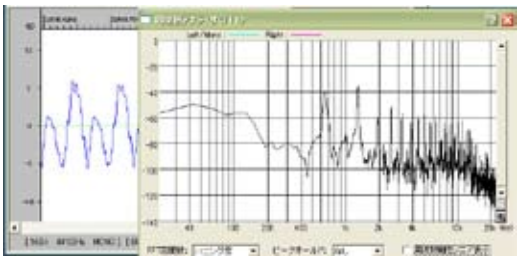
Craftsman made violin



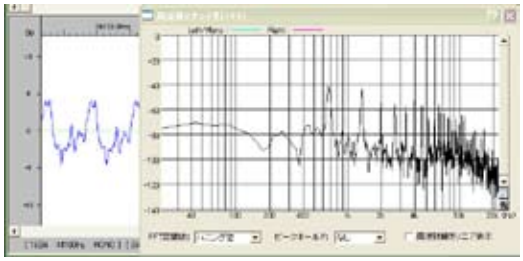
Model 6 (Japanese cedar with arched body)



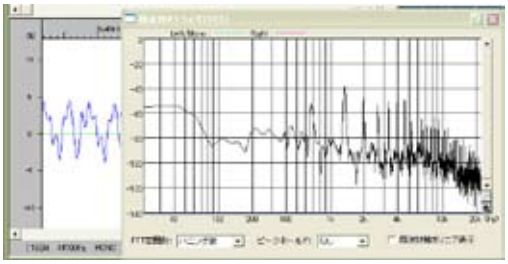
Model 1 (Paulownia with flat body)



Model 4 (Agathis with flat body)



Model 3(Japanese cypress with flat body)



Maker made violin

1. The production of wooden musical instruments is attractive for a lot of students.
2. The violin as the manufacturing object has promoted motivation for creative design.
3. It was effective for the student to learn the all process of design, manufacturing, assembly.
4. Student can learn the fundamental analysis technique of signal processing and FFT through the evaluation of tone.

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