Proceedings of 20th International Congress on Acoustics, ICA 2010

23-27 August 2010, Sydney, Australia

Integral curriculum on noise control in Spain: a cooperative task

Romeu J. (1), Genesca M. (1) and Pamies T. (1)

(1) Acoustical and Mechanical Engineering Laboratory (LEAM), Technical University of Catalonia, C/Colom 11 08222 Terrassa Spain

PACS: 43.10.Sv

ABSTRACT

Since the European Directive on Environmental Noise 2002/49 came into effect requiring strategic agglomeration and infrastructure noise maps to be made, the demand on environmental Acoustics knowledge has been boosted in Spain. Currently several groups and companies are available to carry out noise surveys and pointing out the noise causes in different streets or areas of a city. However, a second stage is starting now: once the noise causes are identified, control noise techniques needs to be applied. This fact is supported in the Spanish adaptation of this regulation known as Ley del Ruido (2003) that states that noise control techniques should be applied to minimize the acoustic emission of municipal work activities, municipal devices, infrastructures, road work…This means that a demand on noise control knowledge is arising. This knowledge is scarcely provided in the bachelor degrees currently available in Spain, but there are some master degrees focused in Acoustics. However, it is difficult to find an institution that can cover all the topics needed for a complete Acoustics curriculum. This work analyses the feasibility of creating an integral curriculum in noise control involving different Spanish research groups in order to take benefit of the expertise of each one to cover the legal and industrial needs of Acoustics knowledge. In that way, the teaching effort would be optimized and the appropriate facilities would be available, however funds would be necessary for the mobility of teachers and students.

INTRODUCTION

The release of the Directive on Environmental Noise 2002/49, which requires making strategic noise maps for agglomerations and infrastructure, has boosted the development of acoustical activity in Spain. As a result of the Directive, the Ley del Ruido (2003) (Spanish noise law) has also been released and it limits the levels of noise caused by any source and includes statements as follows:

- Public administrations will promote the use and acquisition of equipment of low noise emission, especially when hiring works or supplies.
- In noise zones caused by infrastructures, noise levels have to be minimized using the best available technology.
- Local regulations have to regulate road work, neighborhood activity (including electrical appliances), HVAC installations, urban cleaning and collection equipment among others.

Apart from that, people's sensitivity towards the noise pollution has increased in parallel to the creation of legal framework, as demonstrated by the appearance of the Ombudsman's monograph on noise pollution (see Contaminación Acústica, El Defensor del Pueblo, 2005(in Spanish)).

The social and legal interests on fighting noise pollution contrast with the difficulty of getting a higher education in Acoustics Engineering in Spain. Acoustics Engineering B Sc degree doesn't exists and just the Image and Sound Engineering degree focuses part of the curricula in subjects related to Acoustics. An Image and Sound Engineer is a Telecommunications Engineer with specific knowledge on image and sound, traditionally image has more weight in the curricula than sound, and the subjects regarding sound are more focused in electro-acoustics than in noise control. However, architectural acoustics and environmental noise subjects are included with also an introduction to noise control techniques such as sound insulation, barriers and room acoustics. Other Engineering or Architecture B.Sc degrees rarely include noise or vibrations control in the curriculum and if they do, it is just a single optional subject. Consequently, it can be stated that there is just one degree in Spain that provides basic knowledge in Acoustics.

The lack of professionals who specialize in noise control and vibration may represent a drawback to the increasing interest in acoustic pollution arisen by the Directives and the law introduced at the beginning of this section. This is because just a few professionals will be able to interpret the strategic maps and to develop and evaluate action plans. Also, the lack of expert acousticians on product design can limit the market of certain industrial products, in the case of not comply with acoustic regulations or in the case of being more noisy than the competition.

The depicted situation stresses the need for professional specialists on noise and more specifically on noise control. The current process of adaptation of the university degrees to the European Higher Education Space is an opportunity to create the appropriate degree, but it seems unlikely that an Acoustic Engineering B Sc degree appears, so an Acoustics Engineer-

ing M Sc degree may be the best option. At that aim, in the recent years, several M Sc degrees on Acoustics have been created in Spain. The scope of this paper is to determine whether the current M Sc degrees available in Spain cover all the topics related to noise control, and also looks at the possibility of creating an integral M Sc degree involving different research groups.

NOISE CONTROL AREAS COVERED BY CURRENT MASTERS

Regarding the INCE classification of subjects, noise control knowledge can be classified into different areas. The first one deals with emission focused on noise sources such as vehicles, industrial machinery and equipment which is hardly approached in the current master degrees in Spain. The subject physical noise phenomena, mechanisms of noise generation for theoretical sources is taught in most of the master degrees together with propagation (in the atmosphere, enclosed spaces, ducts), transmission and scattering, however, radiation of solids and aero acoustic noise is frequently not included in the curricula. In the area of noise control elements barriers, screens, shielding and sound isolating elements are treated vastly while topics like absorptive materials and noise attenuation and transmission in ducts are not so frequently considered, and noise control techniques like active noise control, noise control by operational changes, and configuration or design changes for acoustic purposes are hardly ever treated. The topic vibration and shock is rarely treated in depth so vibration propagation, isolators and attenuators, shocks and vibrating structures are often not covered. However, the most treated topics are Immission: Physical aspects of environmental noise and Analysis. On one hand, regarding immission, noise surveys, community noise control, in-plant and outdoor plant noise control are vastly treated, just some topics related to building noise control such as sound fields in rooms, sound-insulating, flanking transmission, HVAC, elevators, piping remain scarcely introduced. On the other hand, regarding Analysis, in most of the master degrees instruments for noise and vibration are introduced as well as measurement techniques such as acoustic intensimetry or modal analysis, however microphone array or acoustic holography are hardly included. Also basic knowledge in signal processing is provided, and the students are introduced to the use of modeling, prediction and simulation software regarding traffic, road, airplane or industrial noise propagation outdoors and also indoor propagation models. The main lack within Analysis area seems to be analytical methods such as FEM, BEM and semi-analytical methods like SEA, or modal analysis theory and also modeling and prediction of vibrations generation and propagation in the ground and into the buildings.

The fact that Immision and Analysis are the most covered areas in the master degree studies matches the fact that so far in Spain a need for noise evaluation has been boosted due to the direct impact of the legislation. In the current stage it seems that a knowledge exists on how to asses noise levels by direct measurement or by simulation. However, in order that the information obtained from measurements or simulation becomes useful, it is necessary to move forward to noise control techniques. This means that after being able to determine that a noise level is over the limit, and identify its noise source, it is necessary to have the knowledge to reduce the immission level of the source. As can be seen from the review of the master degrees curricula, basic knowledge on passive control techniques is available, but no acoustic design concepts are taught such as vibrating structures and acoustic generation, analytical methods (FEM, BEM), statistical methods (SEA) and their application to specific problems such as ventilation ducts or vehicles. Also, advanced noise control techniques such ANC are not included.

In order that the existing noise surveys have an impact on the society by decreasing the noise annoyance it is necessary to provide knowledge on active control techniques. Nevertheless, noise control involves a wide range of acoustic fields and so it is difficult to find a single institution that is expert in all of them. This is why the present communication explores the idea of a cooperative master degree in noise control involving different Spanish research groups in order to cover most of the areas in noise control minimizing the teaching effort.

Moreover, although there is knowledge regarding noise measurement techniques and prediction and simulation tools, it is often limited to a user level, not to a developer level. Therefore an effort to provide in depth knowledge in these areas should be done, so acoustic experts are able to develop new models, or measurement techniques to face special cases, and to understand the theoretical concepts underlying the models and its limitations. The same is applicable to passive noise control techniques; knowledge should be provided so new absorptive materials, filters, mufflers, sources enclosures can be designed and applied to industrial devices in order to reduce the noise emission.

It is true that in an Acoustics master degree there are some fundamental subjects such as mathematic methods that can be taught by non-Acoustics experts, however, most of the subjects needs to be taught by experts in Acoustics provided with the appropriate numerical tools and experimental facilities that are not easily obtained. Moreover, there is a wide range of noise control applications requiring really specific control techniques that are rarely all known in depth by a single research group that has the appropriate facilities. Therefore, it seems reasonable to study the feasibility of creating a master by combining knowledge and facilities from different research groups. There are many small/medium sized groups in Spain that can't teach a master degree alone, but they could if they would do it together. Next section depicts the map of Acoustics research groups in Spain in order to expand the contents of the current available master degrees by means of collaboration of different groups.

NOISE CONTROL AREAS COVERED BY RESEARCH GROUPS

There are two main types of existing research groups in Spain: university groups, which often also teach, and not university groups, which in principle have no teaching. This second group includes research groups such as CSIC (Centro Superior de Investigaciones Científicas) or groups included in technology centres. Although it is true that members of these research groups can act as invited teachers to the Masters degrees, they don't seem to be able to teach a whole master themselves. Consequently, the picture of the research groups in Spain is restricted, in this paper, only to university groups.

Below these lines there is a list of existing groups and their areas of expertise, drawn mainly from the publications found in international journals and conferences.

University of Sevilla.

This research group is mainly devoted to research on the field of wave propagation on soils and particularly of train induced vibrations.

Engineering Acoustic Laboratory (LAV), University of Cadiz.

Their work focuses on environmental noise and its sociological effects. This group is authorized by the public administration to carry on noise measurements in boats.

Numerical Methods and Signal Processing of Dynamic Systems Research Group, University of Granada.

This research group, as can be inferred from the published work, mainly focuses its work on the material failure detection by acoustic emission.

CMT-Motores Térmicos. Technical University of Valencia.

It is a powerful group devoted to research in combustion engines, including aspects related to noise such as silencers, sound quality, and mechanisms of noise generation.

Acuoustic and Mechanical Engineering Laboratoy, Technical University of Catalonia.

Research group working in active control and source location techniques. Environmental noise monitoring and semianalytical modeling of vibration propagation is also carried out.

Applied Acoustics Group. University of Leon.

From the published work found, it seems that the main activity of this group is devoted to environmental noise and community noise control.

Acoustic Laboratory, University of Extremadura.

Its main activity is devoted to environmental noise and the realization of noise surveys since most of their published work is in this area.

Applied Physics Department. Technical University of Valencia.

Their main research is focused on sound insulation of building walls, they make use of advanced techniques such as holography.

Non Linear Physics Research Group, Technical University of Valencia.

This is a multidisciplinary group that in the field of Acoustics carries out basic research in the physical phenomena of sound.

Building Acoustics Group, Technical University of Madrid.

Their work seems to be mostly based on acoustic insulation of dwellings, and the study of the acoustic behavior of building materials.

Applied Physics Department, University of Valladolid.

Most of the research of this group is based, as can be seen from most of the published work, in studying sound propagation outdoors.

M2NICA-Model and Numerical Methods in Engineering and Applied Sciences, University of Vigo.

This group is mainly composed by Mathematician researchers focused on numerical solutions for physical acoustic phenomena and sound generation.

I2A2- Instrumentation and Applied Acoustics Research Group, Technical University of Madrid.

This research group bases their work in environmental Acoustics and noise measuring instrumentation, including signal processing capacities.

Mechanical Engineering Group. Technical University of Valencia.

The first main research line focuses in the theoretical and experimental study of silencers; the second one focuses in mechanical failure due to vibration and in the correlation of FEM models to experimental measurements.

A summary of topics covered by all the research groups can be seen in Table 1, according to a slightly modification of INCE classification of subjects.

LINKING RESEARCH WITH MASTERS

Table 1 shows the subjects taught in the current masters degrees. Every group in charge of a master degree has an associated letter that also identifies this group as a research group. For instance, *a* refers to a group as a research group and also as a teaching group. A total amount of 9 master degrees has been found, 6 of them depends in some way on research groups, the rest are taught in universities that has no significant scientific output in subjects related to noise control. Most of the master degrees focus in building or environmental acoustics, therefore topics related to noise control are rarely included in the curricula as has been summarized before.

In general, lack of correlation is found between the research lines of the groups and the content of the master degrees. It is true that there is not necessary to be an expert researcher in some subjects to be able to teach them properly, however it is advisable in order to be able to offer a deeper inside in the topic and its applications to those students that want to carry on their master degree thesis in the topic, or even a PhD later.

Analyzing Table 1 by subjects, and beginning by the area of physical phenomena, it can be seen that there is almost no match between research and teaching. Physical mechanisms of noise generation are almost not considered in most of the masters and surely the comprehension of this subject is a milestone in noise and vibration control activities. Propagation in atmosphere and in enclosed spaces is included in all the masters, but there is not scientific output from the teaching group. And propagation in ducts is not included in any master curricula. Nevertheless, there are a couple of research groups which work in that field, but they don't teach a master.

Maybe the different effects of noise (on human, on wildlife, on economic aspects) are not the main topic for a noise control engineering practice, but of course some information, maybe in form of seminars, should be included in the master degree, but little known research is carried out in Spain by university groups from Engineering Schools.

Environmental subjects show the best match between research and teaching, especially in noise surveys, which include both measurement and calculation procedures, but topics related to noise control (in buildings, in plant or community noise) are not as well covered as noise surveys.

Regarding to noise control elements it can be concluded that there is research in Spain, but most of the topics, a part from sound insulation, are not included in masters. Only one group doing research in sound insulation is in charge of a master

degree. Vibration topics register less research in Spain than noise, but a few groups have significant scientific output in this area. Again, these groups are not related with any master.

Finally, Analysis is really important to noise control engineering practice. In that area there are many topics included in masters, and many groups carrying out research and. Although this is the area with the best match between teaching and researching, there are also some important gaps in teaching as for example holography, array measurement techniques and analytical techniques such as SEA. Numerical methods (not as a user of commercial software but as a developer) is not taught by a research group with research output.

All the current masters include 60 ECTS or last for one year. This amount of time is enough to get to a master level in building and environmental acoustics, however, it seems to not be enough to also include noise control techniques in the curricula. In most of the current master degrees, the option of completing the studies with a PhD seems to be just likely in the environmental acoustics field.

Thinking on a Noise Control master degree that attracts foreign students, and that allows the students to do further research in any of the considered topics (e.g PhD) seems to involve some changes in the curricula and the structure. It is not feasible that a single research group could organize such an ambitious master alone because it requires a big effort and also because it doesn't exist a group that is expert in all the areas. The option of adding an extra term to the current master degrees to cover all the aspects of noise control is also not possible without the interaction of several research groups.

Given the depicted situation, it seems that an interuniversity master degree is the best choice in terms of economy and education quality. A 1-year-long master degree focused in noise and vibration control could consists on a first term taught in one school including fundamentals of Acoustics and Vibration (generation and propagation mechanisms) and signal processing (providing the mathematical base required). This doesn't mean that the teaching have to be done by just the group in that school, other teacher from the rest of groups could and should take part in the classes where their experience in the area is relevant. The second term could be non-centralized: Every research group could offer a block of subjects directly related to its research areas for half a term, in that way, the students could attend to two complementary blocs in one term. The master degree could be achieved by the realization of a final thesis to be developed with one or more of the research groups involved in the master.

The advantages of the interuniversity master would be:

- Full cover of all the topics related to noise control
- Subject would be taught by the most expert teachers in that area
- Boost teachers and students mobility
- To favor collaboration between different research groups
- Option to specialize in a topic by doing a PhD in any of the involved Universities.

Obviously, such a structure requires important funds for teachers and students to travel. The option of creating local masters (organized by a single research groups) also requires important investments in order to train teachers and to provide the required facilities, and there is the risk of not having enough students for several master degrees. If there are enough students for one or two master degrees, the fact of having them centralized also requires funds for the students to travel from their cities, or from abroad, to the university where the classes take part.

The information regarding scientific output of the research groups has been obtained from the groups' webs sites, and from the contributions of the members of the groups to international journals and conferences, so it may be incomplete. As a consequence a preliminary assignation of the master's degree contents to the research groups would not be reliable. The authors know about other research groups in Acoustics and Vibration in Spain but they haven't been listed in this paper because recent scientific output in international magazines or conferences couldn't be found (Mechanical Engineering Department of the University of Basque Country, Mechanical Engineering Technical Studies and Research Center of the University of Navarra, Communications Department of the Technical University of Valencia, Mechanical Engineering Department of the University of Cantabria, Fluid Mechanics Department of Technical University of Catalonia and University of Oviedo....or individuals working on specific topics such as gear noise in University of Cartagena for example). All these groups haven't been considered because of the objective criteria based on scientific production used, but obviously they should be taken into account in case of further development.

The authors want to apologise to the research groups that are unknown because they may work in distant areas from the research field of the authors.

CONCLUSIONS

As far as there is not the chance to obtain a graduate degree in Acoustics in Spain apart from the B Sc in Image and Sound Engineering, more devoted to sound and signal processing, it seems clear that noise control engineering subjects should be acquired through a M.Sc degree. Several master degrees exists in Spain, but all of them are devoted to environmental noise and architectural acoustics, probably because part of them are related to research groups in environmental topics. However, most of master degrees are not related to research groups involved in noise control topics as development of numerical or analytical methods, vibration generation and propagation in structures and soils, sound radiation or advanced measurement techniques as arrays or holography. There exists research in those topics in Spain, but for any cause, most of the research groups involved in noise control topics are not in charge of any master.

A M Sc in Acoustic Engineering, focused in noise control topics could be afforded by an interuniversity program. The first part of the courses should be done in just one university and after that, students should follow different specialized courses on advanced topics in the best center available, maybe for a half of the second semester, in order to be able to follow two different main topics in the second term. After that, a master's final thesis or start a Ph D thesis could be easily done in whatever of the universities included in the program.

Topics	INCE Classification of Subjects							
Emission	**11**	**12**	**13**	**14**				
Master	k		k	b				
Research	e		k					
Physical Phenomena	**21**	**23**	**24**	**25**	**26**			
Master	b	a,b,k,g,i,p	b,k,i,p	a,i,p,q,r				
Research	e,j	h,j,m	i		e,f			
Noise Control Elements	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**
Master	a,k		a,c,b,i,k,g,q,p,r		q,i,p			
Research			g,d	e,f	g		e,f	k,n
Vibration	**41**	**42**	**43**	**43b**	**44**	**46**	**47**	**49**
Master						q,c		b
Research		f,j	f,j	m,n				
Environmental noise	**51**	**52**	**53**	**54**	**55**	**56**		
Master	c	b,i	a,b,i			c,a,b,q,k,g,i,p,r		
Research		b		a		a,b,c,i,k,n		
Effects of noise	**61**	**62**	**64**	**65**	**66**	**67**	**69**	
Master		b,i,p						
Research					a,i,k			
Analysis	**71**	**72**	**72b**	**74**	**75**	**75b**	**76**	**79**
Master	a,c,i,p,b,k,g,r	a,b,k,i,p		b,k,I,r	c		b,k,g,i	a,g
Research	k		k,l,g,n	k,g,m,n	e,f,,j,m		g,k,m,n,e,f	e

Table 1. Noise control topics covered by different research groups in Spain. Codes of topics can be found at annex and are a slightly modification fo the INCE classification of subjects. Letters are linked with research groups.

ANNEX

Codes of table 1 according to the classification of the Noise Control Engineering Institute. Expressions in italic are small changes or additions respect the original classification. Some have been ignored in order to restrict the volume of information.

EMISSION: NOISE SOURCES (Noise generation and control)
11 Noise-generating devices (including components and subassemblies)
12 Stationary noise sources
13 Moving noise sources including aircraft
14 Specialized industrial machinery and equipment
PHYSICAL PHENOMENA
21 Physical mechanisms of noise generation
22 Natural sources of noise
23 Propagation, transmission & scattering of sound (general wave equation)
24 Sound propagation in the atmosphere
25 Sound propagation in enclosed spaces
26 Sound propagation in ducts
NOISE CONTROL ELEMENTS (Noise control by external treatments)
31 Barriers and screens, shielding
32 Enclosures for noise sources
33 Sound isolating elements (including panels, partitions and curtains)
34 Filters, mufflers, silencers and resonators (conventional types)
35 Absorptive materials
36 Hearing protective devices
37 Noise attenuation and transmission in ducts
38 Special treatments (including active noise control)
VIBRATION
41 Characteristics of sources of vibration and shock
42 Vibrating surfaces and structures (beams, plates, shells)
43 Propagation in structures (structure-borne noise)
43b Propagation in soils
44 Balancing of rotating and reciprocating machines
46 Vibration isolators and attenuators
47 Vibration-damping materials and structures
49 Effects of vibration and mechanical shock (on man, on structures)
IMMISSION: PHYSICAL ASPECTS OF ENVIRONMENTAL NOISE
51 Building noise control
52 Community noise control
53 In-plant noise control
54 Shipboard and offshore platform noise control
55 Outdoor plant noise control (design and construction)
56 Noise surveys
IMMISSION: EFFECTS OF NOISE
61 Perception of sound
62 Physiological effects
63 Psychological effects
64 Effects of noise on physical structures
65 Effects of noise on animals and other wildlife
66 Sociological effects; community reaction to noise
67 Economic effects
69 Criteria and rating of noise
ANALYSIS
71 Instruments for noise and vibration measurement
72 Measurement techniques
72b Advanced measurement techniques (holography, arrays)
74 Signal processing
75 Analytical methods *(FEM-BEM)*
75b Analytical methods (SEA or others)
76 Modeling, prediction and simulation *(applications)*
79 Psychoacoustical evaluations and testing