

MECHATRONICS IN JOHANNES KEPLER UNIVERSITY IN LINZ, AUSTRIA

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АБСТРАКТ: В этой статье, описаны программа Мехатроники (BSc, MSc and PhD) в университете Йоханнеса Кеплера в Линце Австрии и ее ключевые компоненты, включая обучение, тестирование, оценка, управление и научно-исследовательская интеграция с образованием и развитием в соответствии с потребностями и проблемами отрасли. Эти анализы были проведены в рамках проекта TEMPUS MACH - Разработка магистерской программы и докторские курсы Мехатроники в Узбекистане.

АБСТРАКТ: Бу мақолада Линц Йоханнес Кеплер Университетида (Австрия) мавжуд меҳатроника бўйича бакалавриатура, магистратура ва докторантура дастурларининг асосий ташкил этувчи компонентлари, таълим жараёни, баҳолаш тизими, илмий-тадқиқот интеграцияси ҳамда уларнинг ишлаб-чиқариш талаблари ва муаммолари асосида ривожланиши ёритилган. Бу таҳлиллар TEMPUS MACH-Ўзбекистонда меҳатроника йўналиши бўйича янги магистратура ва докторантура курсларини яратиш лойиҳаси доирасида амалга оширилган.

The Johannes Kepler University (JKU) was established in 1966, in the city of Linz, Austria. Over 19,000 students are enrolled in over 60 modern, hands-on academic degree programs at three faculties – Social Sciences, Economics & Business, Law, and Engineering & Natural Sciences and over 300 full time professors work at the university.

In Austria, there are no admission tests to enter university except for some general prerequisites such as having diploma with transcripts of studied subjects from high school (academic gymnasium) or technical college or professional (craftsmanship) school of 5 years of education. If pupils studying in their middle or high-school fail to pass minimum requirements, they can re-make their failed year for two times and if they can't succeed after two tries, they will be discharged out of their school without high-school diploma that means they can't continue with further education any more.

This is a short overview of Mechatronics education and research program principles at the JKU.

*“The unique curriculum for the **Mechatronics** program is one-of-a-kind in Austria, combining electrical engineering, computer sciences, and mechanical engineering. The university offers both undergraduate and graduate degree programs” - according to the source [1].*

In the program at mean time there are about 800 enrolled students including all BSc, MSc and PhD students. Mechatronics program was launched in 1990 and its length in general 10 semesters of which 6 semesters of BSc and 4 semesters of MSc degree studies.

The mechatronics program is developed within 14 research institutes [2] which are led by 14 full-time professors and their teams of associate and assistant professors, researchers and lecturers. The Mechatronics research institutes are the followings:

Institute of Design and Control of Mechatronical Systems

Institute of Electrical Drives and Power Electronics

Institute of Measurement Technology

Institute of Constructional Lightweight Design

Institute of Machine Design and Hydraulic Drives

Institute of Mechatronic Design and Production

Institute of Medical and Bio-Mechatronics

Institute of Microelectronics and Micro-sensors

Institute of Communications Engineering and RF-Systems

Department of Communications Engineering

Department of RF-Systems

Institute of Automatic Control and Control Systems Technology

Institute of Robotics

Institute of Fluid Mechanics and Heat Transfer

Department of Particulate Flow Modelling

Institute of Technical Mechanics

JKU HOERBIGER Research Institute for Smart Actuators.

This analyses report is prepared based on discussions and talks with leading professors (professor Rudolf Scheidl, Kurt Schlacher, Wolfgang Amrhein), associate professors (Bernhard Manhartsgruber, Peter Hehenberger, Hubert Gattringer), researchers, PhD and MSc students of Mechatronics Engineering program at several research institutes, such as, Machine Design and Hydraulic Drives, Electrical Drives and Power Electronics, Mechatronic Design and Production, Automatic Control and Control Systems Technology, Robotics at the JKU.

General information about educational system at JKU

In fact, the Bologna system is completely implemented in all engineering programs at the university. It is known that one of the main reasons of Bologna system of 3+2 years (BSc + MSc) is to prepare young specialists (engineers) to meet industry needs as earliest as possible with BSc degree specialists at the age of 21 – 22 or 23 years old (latest/oldest). However, in practice this formulation of expectation is not working in most cases. Because industries are not willing to employ BSc degree specialists due to the fact that BSc programs are not capable of providing sufficient skills to young people in 3 years. Thus, industries are still interested in employing MSc graduates who got 5 years of education that corresponds to an old 5 year higher education system of engineering. The last academic degree is PhD that lasts 4 years in general.

Most (almost all) of BSc students will continue after 3 years of their education for MSc degree program because they are aware of industry needs and concerns. Thus, nowadays 3+2 = BSc+MSc is another form of a former 5 year educational system. There are sufficiently good reasons for continuing an old system with some adjustments and some flexibility options. It is less expensive to have young people freely choose for themselves when to complete their degree and instead of speeding up young people's graduation period, it would be more reasonable to extend retirement age of currently working professionals. Besides, early retirement would be more expensive for a state with additional social protection expenses. Young people don't need lots of financial support and social protection unlike senior people. They had better have more relaxed time constraints and when they wish to work, they can come back to work-force whenever they feel it is right time for them. In some of the EU countries, there is a trend going back to an old system of 5 year engineering education, for instance, in Germany due to above stated reasons.

MSc program in Mechatronics at JKU

Most of the (many electives) courses are flexible and very theoretical. Since most students in MSc degree (in Mechatronics) would like to study/get knowledge on advanced level and not lab based hands skills. Less than 50% of the courses have any lab-works or assignments at all. Because most of the lab works are studied profoundly in BSc and high-school.

Main principle of teaching and education in MSc/graduate school is to teach students principles of working hard, efficiently and using appropriate tools/methods. Content of courses is not that much important in many cases as we may presume. In average, MSc students will study 50-60 hours/week including class and outside of class learning hours that is considerably large amount of time. BSc students work even harder and spend about 60-70 hours for studies per week. That is one of the reasons why BSc and MSc students are very competitive and apt to continue their education further.

Mathematics is taught very extensively and profoundly in MSc program of Mechatronics. De facto, professors are aware of the fact that, for instance, differential equations are not frequently used in industry but that does not mean that they should not teach their students. All these understandings and skills in mathematics will help engineering graduates to imagine and conceive given or faced problems much faster.

One of the main concepts and advantages of Mechatronics students is that they are capable of solving a given problem by using whatever available means. Employment after graduation is not an issue at all. Hence, the program is attractive and recruits many top students. Besides, in most of the cases graduates from the

program find appropriate jobs before their graduation. Due to strong and broad analytical thinking abilities of engineering majors in particular, some banks in Germany and Switzerland have started employing engineers. That is also a reason for popularity of engineering programs in Austria alike in Germany.

Every year they (mechatronics program professors and instructors) change or update the lab assignments in applied mechatronics courses leaving only 2-3 labs in hydraulics and control design without updates, for instance. Because they find it boring for course instructors/teachers and teaching assistants (TAs) and students may use notes from the previous years. Instead, continuous updates of lab assignments are achieved using currently on-going PhD projects' test/experiment rigs/benches. PhD students will also serve as TAs part of their academic responsibilities by teaching lab works and advising BSc and MSc students in their thesis works.

Mechatronics MSc program at the JKU is composed of 54 ECTs (mandatory courses: 3 MATH courses (Optimization, Geometric-modeling: splines), 2 Physics (electro-magnetics, soft-matters), and Computer Science (Java, Assembler, C) courses)=20 ECTS + major mandatory courses = 39...54 ECTs + 7 free electives (any area) + MSc thesis == 120 ECTs in total. Almost all courses in MSc program are taught in German. Most of the courses taught in MSc program are advanced level theoretical courses with applied mathematics, high level physics and scientific computing/programming in mechatronics program, for instance. The reason for that is many applied and laboratory courses are taught in BSc program and/or even earlier in high-school (gymnasiums), technical colleges and professional/craftsmanship schools. Computer and programming skills of students are very strong. All students are very good at programming using technical computing languages such as C, Java, or freeware languages, viz. Scilab, Python, Octave and commercial software packages, such as, MATLAB/Simulink, MAPLE, MATHEMATICA and MathCAD.

Mechatronics Courses [3]

Courses are grouped in sub-units of core specialization areas:

- Mandatory courses for all sub-majors of Mechatronics program are:
 1. Mathematics
 2. Mathematics
 3. Numerical Analysis and Optimization
 - Physics
 1. Physics
 2. Physics
 - Computer Science
 1. Systems programming
 - Majors:
 1. Electrical Drive Systems
 2. Automatic Control and Robotics

3. Mechatronic Design
4. Sensors and Instrumentation
5. Mechatronics and micro-systems technology
6. Communications and RF-Engineering
7. System Analysis and Optimization
8. Mechanics of Solids and fluids

Students don't have to purchase any text books for their studies; because all necessary lecture notes and reading materials are completely developed by course lecturers and professors. Students will get all those notes for free of charge or pay very small price that covers copying and plus small additional administrative costs. Besides, literature sources are available at the library of the university or corresponding departments. In the US universities, this is different because professors don't write or prepare their lecture notes or books there! That leads to use other literature sources – books that make students purchase additional books.

Students choose their elective courses in their majors that will be useful for their theses. Most of the MSc students build laboratory test benches to validate their theoretical and computer modeling results of their theses. Building laboratory rigs of MSc thesis works is financed by the department's budget earned from industrial projects in general. Total amount of sum for such purposes is set to be around 5000 Euros per student to make test rigs or necessary components in outside companies. About 50% of theses are done based on industry projects. Another way of creating or using test rigs or benches for MSc theses is logical continuation or part of on-going PhD projects at each department.

Independent learning is strongly encouraged in all courses. In some courses, there are student group based projects not in all courses of Mechatronics program. Besides, the help line for students (BSc, MSc and PhD students) is well set up and can meet their professors and teachers at any convenient time for them and there is no need to fix appointments in advance via emails or phone calls. There are no fixed office hours for students to meet Mechatronics program professors. One of the reasons for such flexibility is that this program has smaller number of students in comparison with other programs of the university. This makes the program studies more flexible and accessible when difficulties are faced by students. This is not the case with other programs (for instance business science majors) of the JKU where there are too many students.

About 60% drop outs in Austria and Germany in engineering programs mostly within the first year. The reason for that is either they can't follow up the program or can't meet the program requirements or switch their majors.

There are no publication requirements for MSc students in order to graduate. There are some exceptionally good theses or graduation works when MSc or even BSc students publish one or two papers in peer reviewed and respectful international journals.

If students fail in their exams, they can have 3 trials to pass an exam plus (in addition) 2 trials in front of an examining board (senate) , consisting of 3 professors. There is no fee for re-taking exams. Most engineering MSc students are not concerned to be “A” student in Austria because employers/companies mostly rely on measuring skills of graduates via interviews and their presentations, specialization skills and questioning what they have done in their MSc theses and other skills such as team working and interpersonal communication skills. For instance, currently there is only one “A” student with Grade Point Average (GPA) of 1.0 (1.0 corresponds for Excellent “A”, 2.0 for Good “B”, 3.0 – Satisfactory “C” and 4.0 – Fail “F”) out of 40 students studying in Mechatronics program. GPA matters only if the graduate wishes to pursue academic career path such as further education in PhD or even further for Post Doctoral studies.

All MSc students work really hard in order to meet the program requirements and perform their MSc thesis in high quality of research. For instance, a second year graduate student - **Lukas M**, whose MSc thesis is dedicated to hydrostatic journal bearing optimization in order to reduce or diminish friction. He has developed a computer model in Abuqus software (Computer-Aided-Engineering) package. He also knows and uses free-ware programming language *Scilab*. He has also developed a complex Simulink model with his own Simulink sub-system library model blocks and is now working to build a laboratory test bench to test his simulation results obtained from computer models by using his department’s financial support. What he has done by now is high quality scientific work that can be also published in peer-reviewed journals. Another MSc student is **Harold K**, whose MSc thesis is devoted to Hydraulic Buck Converter. He has built very powerful/extended Simulink model of his thesis simulation model and working on building a test rig for about 3000 Euros by ordering its components to be made at an external company via support of his department’s budget.

About 20% of student exams are available on-line. A major focus in learning outcomes is given to gain knowledge and understand a few things profoundly but not many items on the surface. There are course evaluations at the end of courses. The evaluations are carried out by students via on-line questionnaire using scores 1 (very good) to 5 (very bad). The most general questions of course evaluations are the followings:

- Gender of a student
- How do you assess the professional as well as the content quality of this course?
- How would you assess the didactic/methodical quality of this course?
- How would you like to assess the level of difficulty of this course?
- How would you value the pacing of this course?
- Do you find this additional work?
- The questions of this questionnaire were clearly articulated for me.

All education in BSc, MSc and PhD are absolutely free of charge for all Austrian citizens. There is a small charge for student union membership that is about or less than 300 Euros for whole educational period.

PhD studies and researches in Mechatronics

PhD student in mechatronics of the JKU is considered as a researcher and not like a PhD/doctoral student in other European or US universities that makes a difference in requirements of official credits of taking specific courses. PhD students are not required to have pre-fixed or scheduled courses for their graduation to collect ECTS credits. Of course there are small number of required courses which are quite limited in number of hours and workloads.

Successful completion of PhD dissertation or study is linked with reputation and responsibility of a professor and strong motivation and competence of PhD candidate. In general, study period at PhD is four years according to pre-fixed contract base position alike full time employment. PhD student's general workload is as following: legally they are allowed to work maximum 48 hours of which approximately 50% of their work is their research, of which 80% work is his dissertation project works and the rest is other research projects of his department or lab, and 40% of his work-load is teaching and the remaining 20% is administrative works. Teaching assistantship responsibilities, in other words their contributions in specific teaching responsibilities and duties, of PhD students are mostly defined by their professors. Success rate, successful completion of doctoral degree in 4 years, of PhD students at the JKU is over 95%.

There are no official fixed evaluation procedures to assess progress of PhD students at the JKU that is different from the doctoral school procedures at other leading European technical and engineering universities; for instance, Turin Polytechnic Institute (Italy), KU Leuven (Belgium), KTH - Royal Institute of Technology (Sweden) or University of Leeds (UK), where in general evaluation of PhD student progress should take place once in every academic year. For PhD students, minimum 3 publications are required and all papers must be published in peer-reviewed ISI journals or one of them in respected peer-reviewed conference proceedings. In general, PhD students publish 5 papers by the end of their doctoral degree studies. This is also different at some respectful European universities; for instance, at Turin Polytechnic Institute, Italy and University of Leeds, UK, there are not any requirements for publications to defend doctoral thesis.

PhD positions alike any staff positions are fixed, for instance, at the Institute of Machine Design and Hydraulics Drives, there are 3 PhD positions available in general. Scientific and research competence of all PhD students in mechatronics program are very strong that can be explained well developed BSc and MSc programs from which all PhD students gain all necessary skills for their future doctoral studies.

The PhD positions are funded and supported by the projects and programs from industries or Federal government programs of Austria. In general, annual cost of

one PhD student is as follows: 46000 - 48000 Euros for salary. That also depends on student's age and family status. Also, in addition to that funding from industry, research projects and 5% of teaching, travel, room (lab/office space), equipment make up about 50 000 Euros annually. So, in total annual cost of one PhD student is around 100 000 Euros.

As a summary, the following points can be articulated.

- At the JKU, the Mechatronics program is well advanced, structured and systematized according to the research niches of 14 professors, who are renowned professors in their fields of research not only in Austria but also in the world.
- There is strong integration of research and education in the program. All PhD dissertation related projects inter-connected with industry problems or future research and development projects. All PhD dissertation works are state of art research works that are focused on innovations.
- Cooperation and collaboration between academia and industry is well set up and exemplary.
- Future development trends of the program and research areas are far more advanced and well identified to compare with many other top engineering universities in the EU.
- Only small drawback, maybe in the future, is that all programs are taught only in German that might put some limitations to recruit international students and market the existing programs at the JKU for others whose communication language is English, for instance.
- In the development of all programs and institute facilities, the role of the Austrian government/state support has been vital, is essential at mean time and will be imperative in the future.
- The whole program is so well advanced and developed, systematically well structured and integrated with current and future needs of relevant industries that is recommendation not only for newly created or developing engineering programs of universities in developing countries but also to many renowned polytechnic universities of the EU, e.g. Sweden, Italy, France and UK.
- All of these analyses have been conducted within the framework of the TEMPUS project MACH: Introduction of new Master program and Doctoral courses in Mechatronics in Uzbekistan. More information about the project can be found from [4]. Similar analyses of Mechatronics program structure and development at KTH – Royal Institute of Technology (the project grant-holder institution) and KU Leuven are envisaged to carry out.

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