TALLINN UNIVERSITY OF TECHNOLOGY
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Department of Electrical Power Engineering and Mechatronics

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# PCB ASSEMBLY LINE ROBOTIC SYSTEM AND GRIPPER OPTIMIZATION

PCB KOKKUPANEKULIINI ROBOTSÜSTEEMI JA HAARATSI OPTIMEERIMINE

MASTER THESIS

MECHATRONICS PROGRAM

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# CONCLUSION AND RESULTS

The topic of the given thesis derived from a problem with a PCB assembly line project that did not satisfy the specification agreed with the client. The main problem was that the agreed cycle time was significantly longer than it should have been. The first step towards improving the project so that it satisfies the specification requirements was to make analyses and determine the possible problems. It was known before starting this thesis that the part of the system which needs to be improved is a pick and place robot system.

The main part of the robot system is the robot itself; hence, the existing robot was analyzed starting from when the robot was chosen. By the thesis author it was determined that other robots could have been chosen and according to that other robot systems could have been developed. The robot choice was made basing on the experience of the IPTE specialists. Unfortunately, the robot system did not perform according to the robot specifications. It moved slower and with less accuracy than specified which led to longer cycle time. To improve the already working solution, a decision to choose a new robot system was made. This decision was based on reliance on not only experience but on the use of scientific methods. Also, more analyses and simulations were performed. Suitable scientific methods for choosing a new robot, MCDM method and VIKOR sub method were chosen and explained. Analyses were made explaining why IPTE engineers chose the Epson SCARA robot. Other robots that were considered suitable were analyzed and compared with Epson SCARA. Other alternatives of SCARA robots from different manufacturers were proposed. Other types of robots were considered and their work concept was explained. Suitable alternatives of Cartesian and Delta robots were proposed.

Subjectively Omron X Series 1100 Delta was chosen as the most suitable robot to solve the problem with cycle time. To scientifically prove that Omron's delta is suitable, MCDM method was applied using compromise ranking method (VIKOR) which indeed gave Omron X series Delta the best result for the given PCB assembly line application. To prove again that the choice was done correctly, a simulation on the real Delta was done. Results of the simulation showed that Omron X delta robot with 1,5 kg gripper performs assembly faster than Epson SCARA. Delta simulation on the real robot showed that with the same parameters delta performs a cycle 1,54 times faster than SCARA. The chosen delta robot was analyzed and explained in more detail after confirming that it fits the requirements of the PCB assembly line. For a new robot system, it was necessary to design a new gripper which will suit the specialty of the new robot and the project. New gripper concept was analyzed explaining which functionality the new gripper would need to have. Gripper types were explained in order to understand which gripper design needed to be made. New gripper's components were analyzed explaining how they work and why they are necessary for the gripper to work properly. To decide on how many nozzles a gripper would need to have, a special test stand was made, where a series of tests with different nozzle configurations were conducted. The tests helped to determine which kind of nozzles should be used in the future for the gripper's design. For choosing the correct cylinders, SMC software was used and also extra calculations were made to decide which cylinders would be suitable for the new gripper. Also, manifold work principle was explained, the manifold was chosen using Festo software. Combining all the choices on the hardware, a new gripper design (using SolidWorks) was made and the model design was accepted into manufacturing the components, after considering all the possible mistakes and eliminating them.

Making changes in the robot system in an already finished project requires considering electrical connection and possible program changes. Already existing connection to the robot was analyzed to determine which parts of it could be reused for the new robot system. Delta robot system connection schematics are shown explaining all the components, and how the connection needs to be done. Schematic changes were done using EPLAN software. Sensors that are used in the robot system were analyzed and their working principle explained. Possible alternative connection solution was proposed, explaining the alternative connection possibilities. Robot control in updated assembly line had to stay preferably similar to the old program. Any robot system program changes will be done by a qualified programmer. The robot will be controlled by the PLC.

Financial aspects of the new solution were presented, showing the amount of resources that will be required to implement changes for the PCB assembly line. Risk assessment was done using FMEA method, by which all the considered risks can be reduced, making sure those risks will not increase after project updates. The solution described in the given thesis can be considered a successful new engineering solution because in theory all the problematic aspects of the old robot system were considered and better solutions were proposed. Future developments would be possible after the new gripper design is tested on the real robot. It is possible that some components still require small changes, which can be done in IPTE and will not change the main concept of the new solution for the upgrade. After the tests, the new gripper will be implemented on Epson SCARA robot to see if it will make any changes in the pick and place process. Further, the new robot system will be purchased and implemented into the assembly line by using the proposed changes in paragraph 3.2. In conclusion, a new gripper was produced (Appendix 11) based on the proposed solution, and the tests will be conducted in the near future.

# CONCLUSION IN ESTONIAN

Käesoleva töö teema lähtekohaks oli probleem PCB kokkupaneku konveieriga, mis ei toiminud vastavalt kliendiga kokku lepitud spetsifikatsioonile. Põhiprobleem seisnes selles, et masina tsükliaeg oli vajaminevast pikem. Esimene samm projekti muutmisel vastavalt spetsifikatsioonile oli teostada analüüs ja leida võimalikud probleemid. Juba enne antud magistritöö tegemist oli teada, et põhiprobleem oli robotsüsteemis, mis vastutas komponentide ladumise eest PCB plaadile.

Peamise osa robotsüsteemist moodustab robot, seega alustati olemasoleva roboti analüüsimist juba selle valimise staadiumist. Autori poolt tehtud analüüsi põhjal leiti, et ka teist tüüpi robotid oleksid antud ladumise ülesande jaoks sobilikud, mis tähendab seda, et oleks võinud arendada ka teistsuguseid robotsüsteeme. Epson SCARA robotsüsteemi valimisel tuginesid IPTE spetsialistid oma kogemustele. Reaalses elus ei toiminud nimetatud robot vastavalt tootja poolt kirjeldatud spetsifikatsioonile. Selle liigutused olid oodatust aeglasemad ja ebatäpsemad, mille tagajärjel masina tsükliaeg pikenes. Antud probleemi lahendamiseks otsustati valida uus robotsüsteem. Otsuse tegemisel rakendati teaduslikke meetodeid, mitte ainult kogemusel põhinevaid teadmisi. Samuti teostati täiendavaid analüüse ja roboti töö simulatsioone. Uue roboti valimisel kasutati MCDM meetodit ja alameetodit VIKOR, mille põhimõtteid on täpsemalt seletatud lõputöö kontekstis. IPTE inseneride valikut analüüsiti põhjendamaks, miks nad just Epson SCARA roboti valisid. Samuti analüüsiti alternatiive ning võrreldi neid Epson SCARA'ga. Töös käsitleti erinevat tüüpi roboteid ning seletati nende tööpõhimõtteid, pakuti välja sobilikud roboti alternatiivid nagu Cartesian ja Delta.

Subjektiivselt valiti kõige sobivamaks robotiks Omron X Series 1100 Delta, et lahendada probleemi tsükliajaga. Omron X Delta sobivuse teaduslikuks tõestamiseks rakendati MCDM meetodit ja VIKOR alameetodit, mille tulemused näitasid Omron X series Delta roboti suurimat sobivust komponentide ladumiseks suurele PCB plaadile. Lisaks teostati Omron X Delta sobivuse tõestamiseks simulatsioone reaalelus. Simulatsiooni tulemused näitasid, et rakendades valitud Delta robotile samu parameetreid (nt haaratsi raskus 1,5 kg) suudaks see teostada sama tsüklit 1,54 korda kiiremini kui Epson SCARA. Pärast roboti valiku sobivuse kinnitamist PCB kokkupanekuliini jaoks analüüsiti Delta robotit süvitsi. Uue robotsüsteemi jaoks oli vaja disainida uus haarats, mis sobiks antud rakenduse ja projekti jaoks. Uue haaratsi kontseptsiooni analüüsiti ning seletati, mis funktsionaalsus haaratsil peaks olema, et see suudaks hakkama saada kõikide vajalike ülesannetega. Töös seletati lahti haaratsi tüübid, et oleks selge arusaam, missugune haaratsi tüüp oleks antud rakenduse jaoks vajalik. Uue haaratsi komponente analüüsiti, kirjeldati nende tööpõhimõtteid ning põhjendati nende vajalikkust. Selleks et teha kindlaks kui palju otsikuid haaratsil olema peaks, valmistati spetsiaalne testimisalus, kus viidi läbi mitmeid teste erinevate otsiku konfiguratsioonidega. Testide abil tehti kindlaks, milline otsikute kombinatsioon on kõikide detailide haaramiseks sobivaim. Uue haaratsi jaoks sobiva pneumaatilise silindri valimiseks rakendati SMC tarkvara ja tehti ka käsitsi arvutusi. Samuti seletati lahti kollektori tööpõhimõte, kollektor valiti Festo tarkvara abil. Kombineerides kõiki riistvaralisi valikuid, loodi uue haaratsi disain (kasutades SolidWorks'i) ning pärast kõikide võimalike vigade arvestamist ja elimineerimist saadeti haaratsi detailid tootmisesse.

Muudatuste tegemine valmis rakenduse robotsüsteemis on keeruline, kuna peaks arvestama ka võimalike muudatustega riistvara ühendamise viisis ja tarkvaras. Olemasoleva robotsüsteemi ühendamismeetodeid analüüsiti, et teha kindlaks, milliseid komponente saaks uues süsteemis taaskasutada. Töös on esitatud Delta roboti süsteemi ühendusskeem, kus on lahti seletatud kõik komponendid ja ühendamisviisid. Elektriskeemis muudatuste teostamisel rakendati EPLAN tarkvara. Kõiki robotsüsteemis kasutusel olevaid sensoreid analüüsiti ning seletati nende tööprintsiipe. Töös toodi välja võimalikud alternatiivsed ühendamismeetodid. Roboti juhtimise põhimõte uuendatud kokkupanekuliinil pidi jääma sarnaseks olemasoleva robotiga. Robotit hakkab juhtima PLC.

Töös toodi välja ka finantsaspektid, näidates kui palju rahalisi vahendeid oleks muudatuste elluviimiseks tarvis. Kasutades FMEA meetodit tehti ka riskianalüüs, mille järgi saab vähendada kõiki võimalikke riske, kindlustades et riskid pärast projekti muutmist ei suureneks. Antud magistritöös väljapakutud lahendust võib pidada edukaks inseneri-lahenduseks vana robotsüsteemiga seonduvatele probleemidele, kuna teoorias arvestati kõikide probleemidega ning pakuti välja parem lahendus. Süsteemi edasiarendamine saab võimalikuks pärast uue haaratsi testimist reaalse Delta roboti peal. Alati jääb võimalus, et mõningad komponendid vajavad veel väikseid muudatusi, kuid neid saab teha IPTE-s ning need ei mõjutaks uue süsteemi põhikontsepti. Pärast haaratsi testimist kinnitatakse haarats Epsoni SCARA külge ning vaadatakse, kas see muudab ladumise protsessi. Kui Epson ei näita paremat tulemust ka uue haaratsiga, siis ostetakse uus robot ning viiakse ellu peatükis 3.2. kirjeldatud muudatused masinale. Uus haarats (vt Lisa 11) valmistati vastavalt töös esitatud disainile ning selle testimist hakatakse teostama lähitulevikus.