

**OP 3.2.1**

**3D Design and modelling**

**Version 3.0**

**The training course developed within the project of the European Commission program Erasmus+ «**Development of a network infrastructure for youth innovation entrepreneurship support on Fablab platforms» (561536-EPP-1-2015-1-UK-EPPKA2-CBHE-JP)

<http://fablab-erasmus.eu/>

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**Document Information**

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| 2.0 | 05/10/2017 | Draft | Circulation of the 2st DRAFT version (2nd level check) | U Ghent |
| 3.0 | 01/11/2017 | Final | Final version | BNTU |
|  |  |  |  |  |

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**Course Descriptors**

|  |  |
| --- | --- |
| **Course title:** | 3D Design and modelling |
| **Course unit code** | 3Dmod |
| **University delivering the course:** | KhNUE, IASA-KPI, TNTU, BSU, BNTU |
| **Type of course unit** | Optional |
| **Level of course unit** | Masters level |
| **Number of ECTS credits allocated** | 3 Credits (75-90 hours of student work) |
| **Mode of delivery** | lectures, seminars, business games, independent work, distance learning… |
| **Prerequisites and co-requisites:** | Students enrolled in this course would have ideally passed an Engineering and IT programme |

**Learning outcomes**

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| --- |
| **Learning Goals:**  to teach students the methodology of creating a 2D and 3D models;  to develop the students' skills of spatial thinking while modeling 3D scans;  to acquaint students with modern software designed for 3D modeling in solving engineering problems;  to teach students a various ways and methods of constructing 3D models in CAD systems;  to form students' understanding of the G-code language;  to familiarize students with the difficulties and peculiarities of creating spatial connections;  to form students understanding of the typical errors that arise when building 3D models for printing.  **On successful completion of the module, students will be able to:**  creating two-dimensional models;  creating essentially three-dimensional objects with the help of subtractive production technologies, to be able to represent an object in the form of an ensemble of its faces with various connections;  constructing three-dimensional models in modern CAD (CAD) systems;  working with slicers;  ways to eliminate the discrepancy between the geometry of three-dimensional virtual and material models in additive production, and also the features of building spatial connections;  scan 3D objects. |

**Course contents**

|  |
| --- |
| 1. 2D-modeling  1.1. Software review for creation 2D-models  1.2. Creation of simple 2D-models  1.3. Creation of complex 2D-models  1.4. Features of modeling objects for engraving and cutting  1.5. Transition from 2D-models to 3D-models  2. 3D-modeling  2.1. Software review for creating 3D models  2.2. Creation of simple 3D-models  2.3. Creation of complex 3D-models  2.4. Recommendations for improving the quality of 3D-printing  3. 3D scanning and recognition  3.1. Principles of 3D Scanners  3.2. Scanning of 3D-objects |

**Recommended or required reading**

|  |
| --- |
| **Main:**   1. <http://pechat-3d.ru/3d-printer/istoriya-razvitiya-3d-pechati.html> 2. <http://3dtoday.ru/wiki/> 3. <https://3dprinting.com/what-is-3d-printing/> 4. <http://3dtoday.ru/wiki/3dprint_basics/> 5. <http://3dtoday.ru/wiki/3d_pens/> 6. <http://autodeskeducation.ru/study/fusion360/fusion-features/> 7. [https://autodesk.com/products/inventor/](https://www.autodesk.com/products/inventor/) 8. [http://solidworks.com/](http://www.solidworks.com/) 9. [https://plm.automation.siemens.com/](https://www.plm.automation.siemens.com/) 10. <https://3dprintexpo.ua/ru/article/obzor-luchshih-universalnih-slayserov-dlya-podgotovki-k-3d-pechati-61468> 11. <https://3deshnik.ru/blogs/akdzg/obzor-osnovnyh-nastroek-slajsera-cura> 12. [https://simplify3d.com/support/print-quality-troubleshooting](https://www.simplify3d.com/support/print-quality-troubleshooting) 13. <https://3d-daily.ru/equipment/3dscan-type.html> 14. [http://aniwaa.com/3d-scanning-technologies-and-the-3d-scanning-process/](http://www.aniwaa.com/3d-scanning-technologies-and-the-3d-scanning-process/) 15. [http://instructables.com/id/Laser-Cutting-Basics/](http://www.instructables.com/id/Laser-Cutting-Basics/) 16. <https://ru.wikipedia.org/wiki/%D0%92%D0%B5%D0%BA%D1%82%D0%BE%D1%80%D0%BD%D0%B0%D1%8F_%D0%B3%D1%80%D0%B0%D1%84%D0%B8%D0%BA%D0%B0> 17. <http://reklab.ru/articles/tech-types/> 18. <https://inkscape.org> 19. [http://coreldraw.com](http://www.coreldraw.com) 20. [http://adobe.com](http://www.adobe.com) 21. <https://obrary.com/products/living-hinge-patterns> 22. <http://academy.cba.mit.edu/classes/project_development/index.html> 23. <http://archive.fabacademy.org/>   **Additional:**   1. <http://3dtoday.ru/wiki/3D_print_technology/> 2. <http://3dtoday.ru/wiki/FDM_printers/#.D0.9A.D0.BE.D0.BD.D1.81.D1.82.D1.80.D1.83.D0.BA.D1.82.D0.B8.D0.B2.D0.BD.D1.8B.D0.B5.D1.8D.D0.BB.D0.B5.D0.BC.D0.B5.D0.BD.D1.82.D1.8B2> 3. <http://3dtoday.ru/wiki/3D_print_technology/> 4. <https://habrahabr.ru/post/196182/> 5. <https://3dpt.ru/page/soft> 6. <https://habrahabr.ru/post/196182/> 7. <https://3deshnik.ru/blogs/akdzg/obzor-osnovnyh-nastroek-slajsera-cura> 8. <http://3dtoday.ru/blogs/3dpicasso/cura-your-caring-assistant-in-the-world-of-printing-part-1/> 9. <https://3deshnik.ru/blogs/akdzg/sekrety-slajsera-cura-chast-1> 10. <https://3deshnik.ru/blogs/akdzg/sekrety-slajsera-cura-chast-2> 11. <https://3deshnik.ru/blogs/akdzg/sekrety-slajsera-cura-chast-3> 12. <https://3deshnik.ru/blogs/akdzg/cura-optimizatsiya-nastroek-retrakta> 13. <http://support.3dverkstan.se/article/30-getting-better-prints> 14. <https://3deshnik.ru/blogs/akdzg/obzor-osnovnyh-nastroek-slajsera-cura> 15. <http://3dprintingforbeginners.com/troubleshoot-3d-printing-problems/> 16. [https://simplify3d.com/support/print-quality-troubleshooting/](https://www.simplify3d.com/support/print-quality-troubleshooting/) 17. <http://support.3dverkstan.se/article/30-getting-better-prints> 18. <http://support.3dverkstan.se/article/23-a-visual-ultimaker-troubleshooting-guide> 19. [http://hordaprint.ru/index.php/recommendation](http://www.hordaprint.ru/index.php/recommendation) 20. <https://geektimes.ru/post/253390/> 21. <http://3dtoday.ru/blogs/garremmash/the-20-most-common-problems-of-3d-printing-part-1/> 22. <http://3dtoday.ru/blogs/garremmash/the-20-most-common-problems-of-3d-printing-part-2/> 23. <http://support.3dverkstan.se/article/30-getting-better-prints> 24. <https://make-3d.ru/articles/chto-takoe-3d-skaner-i-kak-on-rabotaet/> 25. <http://can-touch.ru/blog/vse-o-3d-skanerax/> 26. <http://3dwiki.ru/3d-scanner/> 27. <http://robot-ik.ru/articles/kak_rabotaet_ustroystvo_3d_skanerov_tehnologii_i_printsipy_skanirovaniya/> 28. [http://fotokomok.ru/3d-skanery-princip-raboty-i-primenenie/](http://www.fotokomok.ru/3d-skanery-princip-raboty-i-primenenie/) 29. <https://geektimes.ru/company/top3dshop/blog/265626/> 30. [https://youtube.com/watch?v=bZMSt7bC5qE](https://www.youtube.com/watch?v=bZMSt7bC5qE) 31. [https://youtube.com/user/netfabb/videos](https://www.youtube.com/user/netfabb/videos) 32. [https://youtube.com/watch?v=4VBUcKz2Ids](https://www.youtube.com/watch?v=4VBUcKz2Ids) 33. [https://youtube.com/user/meshmixer/videos](https://www.youtube.com/user/meshmixer/videos) 34. [http://osvarke.com/gidroabrazivnaya-rezka.html](http://www.osvarke.com/gidroabrazivnaya-rezka.html) 35. [https://youtube.com/watch?v=4IKlR76oflc](https://www.youtube.com/watch?v=4IKlR76oflc) 36. [http://lincolnelectric.com/ru-ru/support/process-and-theory/Pages/how-a-plasma-cutter-works.aspx](http://www.lincolnelectric.com/ru-ru/support/process-and-theory/Pages/how-a-plasma-cutter-works.aspx) 37. [http://svarkainfo.ru/rus/technology/rezka/vprez/](http://www.svarkainfo.ru/rus/technology/rezka/vprez/) 38. <http://svarkaland.ru/ctati/plazmennaya-rezka-i-ee-osobennosti> 39. [http://gigamech.com/info-mmi/articles-mmi/92-lazer-vs-plasma](http://www.gigamech.com/info-mmi/articles-mmi/92-lazer-vs-plasma) 40. <http://ostanke.ru/chpu/frezernaya-rezka-fanery.html> 41. <https://books.google.es/books?id=8Mp3CwAAQBAJ&hl=ru&num=13> 42. <https://geektimes.ru/post/277290/> 43. [http://vertexn.ru/statii/laser-graver-history.html](http://www.vertexn.ru/statii/laser-graver-history.html) 44. <https://halk.ru/forum/resources/20/download?version=20> |

**Planned learning activities and teaching methods**

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| --- |
| The primary means of learning for student is through practice. This is supported and developed through:  1. Project briefings.  2. Set and self-initiated project briefs.  3. Peer learning.  4. Self and peer assessment.  5. Guest speakers.  6. Group discussions, reviews and critiques;  7. Working on live projects;  8. Mentoring;  9. Independent study.  ***For flexible and distributed learning***  Web-based sessions lead by instructor provide methodological and conceptual framework for students’ learning. All the slides and materials from the class will be available electronically.  Web-based seminars will be used to strengthen the knowledge of newly learned methods and concepts, and to explore their application to particular complex business cases.  Students are encouraged to ask questions and discuss the material in “live” mode online. There will be a web-based message board for the course. Students are welcome to post questions on this board and these discussions will be monitored and facilitated by the lecturer. The main accent will be made on independent learning. |

**Assessment methods, criteria and regime**

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| Progress and learning is assessed not only at the end but throughout the entire course. Evidence of an ability to think through and critically analyse challenges will be highly rewarded in the assessment.  Students' grades will be determined by individual Assignments, based on description of the key idea, normative regulation and steps necessary to build innovation pipeline and supply it with ground-breaking ideas.  The relative weight of Assignment Brief will be set at 100%.  It will be marked on the basis of:  The aim of the report clearly formulated 20%;  Coherence of the arguments and reflection 10%;  Reflection based entirely on the description of facts and events 40%;  Utilization of adequate terminology to describe the project management 20%;  Evidence of activities undertaken. |

**Skills and Personal Development Plan Statement**

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| --- |
| The discipline "3D modeling and design" provides the ability of students:  1) use professional knowledge and skills in practice to solve engineering and practical problems of creating innovative objects;  2) analyze, discuss, formulate and solve problem situations of development and design of new objects and technologies, solve non-standard problems and create fundamentally new approaches in the creation of innovations;  3) to master new knowledge and skills, to improve and self-learn, to continue professional development;  4) be able to work in a team, work on finding new ideas in the team;  5) improve communication skills, including oral and written communication;  6) organize their own activities and efficient management of time;  7) think critically. |

1. **2D-modeling**
   1. **Software review for creation 2D-models**

Process of model creation can be divided into the next steps:

* Creation or import of the 2d-model vector drawing;
* Layout and orientation of the drawing on the desktop;
* Adjustment of power and duration of equipment cutting;
* Cutting out the model;
* Final processing of the finished model (if necessary).

Some manufacturers offer software designed for the equipment produced, but virtually all machines can work with vector graphics *\*.dxf* format.

The translation of vector graphics into a bitmap is quite simple. But the way back, is usually complicated.

In Tables 2.1 and 2.2, a brief description of licensed and free software for creating 2D models is presented.

Table 2.1 – Free software for creating 2D models

|  |  |
| --- | --- |
| Software Name | Software Description |
| **Inkscape** | This is a vector-based image editor with open source code. Has a full set of tools for creating a new model from scratch, as well as changing existing model. |
| **Sketchup** | Free version of SketchUp. Allows you to use most of the tools from the Pro version, except for the Solid tool and the drawing tool. Has an intuitive interface and comes with a large library of objects. |
| **Draftsight** | This is a free alternative to AutoCAD for technical drawing, uses the same commands as AutoCAD. |

Table 2.2 – Licensed software for creating 2D-models

|  |  |
| --- | --- |
| Software Name | Software Description |
| **CorelDRAW**  **https://seeklogo.com/images/C/corel-draw-x8-logo-8E33D20BAA-seeklogo.com.png** | Customizable environment which presents the possibility of pen and touch input, professional photo-editing tools. |
| **AutoCAD**  https://damassets.autodesk.net/content/dam/autodesk/www/products/2017_badges/logo_lockups/responsive-banner/autocad-2017-banner-lockup-1200x132.png | AutoCAD – system for two- and three-dimensional automated design and drawing, developed by Autodesk. AutoCAD is a powerful and flexible tool that allows you to perform a variety of design projects. |
| **Adobe Illustrator**  http://vectorlogo4u.com/wp-content/uploads/2016/09/adobe-illustrator-cc-icon-vector-720x340.png | The software is a powerful tool for working with vector graphics. The product is intended for professional designers, developers of interactive projects and animators. [18]. |

* 1. **Creation of simple 2D-models**

Below are links to exercises for creating simple 2D-models:

<https://inkscape.org/ru/doc/basic/tutorial-basic.ru.html>

<http://web-grafika.pro/verstka-saita-uchebnye-kursy/multimedia-v-obuchenii/vektornaya-grafika/urok-1.-osnovy-raboty-v-vektornom-redaktore-inkscape.php>

* 1. **Creation of complex 2D-models**

<https://inkscape.org/ru/doc/tutorials/advanced/tutorial-advanced.en.html>

<https://inkscape.org/ru/learn/>

<https://youtube.com/watch?v=76MTFWlnO10&list=PLBCEC87C0BCFD1220>

<http://digilinux.ru/2010/01/22/risuem-obyomnyie-izobrazheniya-v-inkscape/>

<https://youtube.com/watch?list=PLynG8gQD-n8BMplEVZVsoYlaRgqzG1qc4&time_continue=408&v=X1SGxjMWbZs>

* 1. **Features of modeling objects for engraving and cutting**

Below are some guidelines for creating a drawing for use on laser equipment:

* when creating a model, draw a red cut line. Do not use filling lines, set the thickness of the lines to 0.1 mm;
* for engraving use lines of black color;
* check the drawing for double or overlapping lines, if possible, get rid of them;
* make sure that you do not use white fill for shapes that can hide lines in the drawing, but not during cutting or engraving;
* first engraving, then cutting out the contour;
* all text must be converted to curves;
* when engraving with a raster pattern, using the values of the shades of gray, you can control the power and depth of engraving, using smoothing to obtain values between surface engraving (rgb – 230,230,230) and deep (rgb – 0,0,0).

After creating the drawing and saving it to *\*.dxf* format, in software designed for specific equipment, you need to configure the model, specifying the behavior of the working body for each color and type of lines. To simplify the adjustment, it is recommended to cut at one speed, choosing the laser power based on the physical characteristics of the material.

**Additional Information:**

<https://geektimes.ru/post/277290/>

<http://vertexn.ru/statii/laser-graver-history.html>

<https://halk.ru/forum/resources/20/download?version=20>

* 1. **Transition from 2D-models to 3D-models**

The main methods of transition are presented in the Table 2.3.

Table 2.3 – Ways to create 3D objects based on 2D-models

|  |  |
| --- | --- |
| Name of the Method | Description |
| Stacking / Layering | There are 2 ways of constructing such a model:   * creating drawings of all necessary parts manually; * Creation of a three-dimensional model in any of the CAD-systems with subsequent export to a specialized program   *Example of 3D model partitioning* |
| Contouring/slicing |
| Joining (with or without hinges) | When creating joint drawings, you must take into account the thickness of the parts to be joined, the width of the machine cut and the error due to the movement of the cutting parts. When building large models, it is possible to use sites that build the necessary connections with the specified parameters, for example, <http://boxmaker.connectionlab.org/> and <http://makercase.com>. |
| Heatforming  bracelet-web | The part is cut out and goes through the temperature and then through a mechanical impacts to impart the desired shape. |
| Slot bending  slot bending_2_web | In open access, there are many templates that give flexibility to wooden plates.  *Template Examples* |
| Stitching | The drawings indicate the holes to be cut for manual stitching. |
| Paneling  The faces by Adrian Bica_collage | This type of connection is an analog of stitching, with the difference that it uses elements cut out from one template most often from flexible materials. |
| Folding  test_unfold | Applicable only to very flexible materials, such as paper, cardboard, leather. |

1. **3D-modeling**
   1. **Software review for creating 3D models**

The two most difficult stages in obtaining a printed part are the construction of a three-dimensional computer model and its subsequent cutting. During the development of the computer simulation industry, all the necessary software products have appeared.

Tables 2.4 and 2.5 provide a brief overview of the main packages for 3D modeling with a description of their main features.

Table 2.4 – Free software for creating 3D models

|  |  |
| --- | --- |
| Software Name | Software Description |
| **TINKERCAD** | TinkerCad is the perfect 3D modeling software for beginners. Its 3D modeling method is like working with LEGO bricks. This software has only web-interface. |
| **3DTIN** | This software by LAGOA is TinkerCad’s main competitor. You can make projections of basic shapes on a plane using simple interface. |
| **Маке** | MAKE is the free version of SketchUp. You can use most of the tools that are in the Pro version, except the Solid tool and the Layout technical drawing tool. SketchUp is very simple to use, has a clean interface, and comes with a big bank of objects ready to be downloaded. |
| **OpenScad** | This 3D modeling software, known to be the favorite of programmers, uses lines of code as functions for creating geometry models. |
| **BLENDER** | Powerful software, capable of creating surfaces of complex shapes. Ideal for creating characters and photorealistic visualizations. |
| **FUSION 360**  **D:\Work\Наука\FabLab\3D Design and Modeling\Fusion.jpg** | Integrated cloud CAD/CAE/CAM tool for industrial design. Allows you to create a unique environment that you can easily adapt to your needs and which will allow you to design almost everything you can imagine using T-spline technology and surface modeling. |

Table 2.5 – Licensed software for creating 3D models

|  |  |
| --- | --- |
| Software Name | Software Description |
| **Inventor**  **D:\Work\Наука\FabLab\3D Design and Modeling\inventor-professional-2016-badge-150x150.png** | Professional system of three-dimensional solid-state and surface parametric modeling, designed to create prototypes of industrial products. |
| **SolidWorks**  **D:\Work\Наука\FabLab\3D Design and Modeling\Solidworks.jpg** | Allows you to develop products of any complexity and purpose. |
| **NX**  **D:\Work\Наука\FabLab\3D Design and Modeling\UGNX.png** | Allows to solve problems of development of a complete computer model of the whole product and its components. |

It is important to understand that the quality of the software will directly depend on the result of printing. Even if the model is made perfectly, the incorrect generation of G-code will lead to poor quality results.

* 1. **Creation of simple 3D-models**

Below are links to exercises for creating simple 3D models:

<http://3dtoday.ru/blogs/3d20/quick-creation-of-simple-gears-in-blender/>

<https://blender3d.com.ua/modelirovanie-pipo-chair-v-blender/>

<https://blender3d.com.ua/tag/model/>

<https://youtube.com/watch?v=KK_g_jiJl0A&list=PLCu1aYg6xRHL2ibOYPFxoV4Gk0sujy90Y>

<http://instructables.com/class/Beginner-3D-Printing-Class/>

<http://enablingthefuture.org/resources-2/getting-started-in-fusion-360/>

<https://damassets.autodesk.net/content/dam/autodesk/www/industries/education/docs/F1iS_Fusion_Trophy_Badge_Guide_vFINAL.pdf>

<https://youtube.com/watch?v=DMFF_yC8SoA&list=PL6PP1q5sXTUzKpG5RxWmWIR3NZpN4y-Eh>

<https://youtube.com/watch?v=22P2-DFNkkQ&list=PL6PP1q5sXTUxx9AExjXyOLws-F7rPmul->

* 1. **Creation of complex 3D-models**

Complex three-dimensional objects are often created in the form of separate simple parts, which later are gathered in one complex object. The creation of prefabricated parts imposes additional conditions on the shapes and sizes of the subassemblies. In particular, special attention should be given to the development of joints. Table 2.6 lists simple tips that help improve the quality of connections when printing.

Table 2.6 – Connection guidelines

|  |  |
| --- | --- |
| Kind of Model | Recommendations |
|  | The internal dimensions are always slightly smaller, while the outer dimensions are slightly larger. |
|  | Latches and flexible parts become brittle when printed vertically due to interlayer adhesion |
|  | Latches and flexible parts printed in the horizontal plane are the most durable.  The part shown at top is better to be divided into two halves for printing, and after connecting them to each other. |
|  | When drawing connections, it is necessary to choose what is more important – the beauty or strength of the structure. |

**Additional Information:**

<http://support.3dverkstan.se/article/30-getting-better-prints>

Below are links to exercises for creating simple 3D assemblies with connections:

[https://youtube.com/watch?v=nngmNos6VI4&list=PLmA\_xUT-8UlKugGDXRAugKLUP4vNFJYXC](https://www.youtube.com/watch?v=nngmNos6VI4&list=PLmA_xUT-8UlKugGDXRAugKLUP4vNFJYXC)

[https://youtube.com/watch?v=2c67o-bXMhk](https://www.youtube.com/watch?v=2c67o-bXMhk)

[https://youtube.com/watch?v=wV4huqHggnk](https://www.youtube.com/watch?v=wV4huqHggnk)

[https://youtube.com/watch?v=30EByYkDb2M](https://www.youtube.com/watch?v=30EByYkDb2M)

[https://youtube.com/watch?v=Z3KoN7cnm8Q](https://www.youtube.com/watch?v=Z3KoN7cnm8Q)

[https://youtube.com/watch?v=DLIfApScqt0](https://www.youtube.com/watch?v=DLIfApScqt0)

[https://youtube.com/watch?v=rTcTbmCuJ9M&list=PL6PP1q5sXTUy5XcVr45xoWeb80AKLilCJ](https://www.youtube.com/watch?v=rTcTbmCuJ9M&list=PL6PP1q5sXTUy5XcVr45xoWeb80AKLilCJ)

* 1. **Recommendations for improving the quality of 3D-printing**

When creating a model, it is very important to understand in what form it will go to print – for some parts it's better to change the location on the substrate, and some are even worth to be cut. Table 2.7 provides simple tips that help to improve printing quality.

Table 2.7 – Recommendations for improving the quality of 3D-printing

| Kind of Model | Recommendations |
| --- | --- |
|  | Parts should be printed hollow, the insides are filled automatically in the slicer according to the hatch pattern. This significantly speeds up the printing and prevents the "swelling" of the model. |
|  | Non-supported ledges can cause printing problems or even not be printed on non-industrial 3D printers. |
|  | The maximum possible slope of the angled ledge without support is 45°. |
|  | Ledges with support from both sides can be printed. This technique is called "bridging". |
|  | A cylindrical hole parallel to the substrate will not cause problems. |
|  | Supports can be built by slicers, but they will have to be removed after printing. It is desirable to try to avoid building supports. |

**Additional Resources:**

<https://habrahabr.ru/post/196182/>

During printing, there may also be a lot of problems with the models, printer, plastic and even with the environment of a different nature. Table 2.8 examines the most common problems and their solutions.

Table 2.8 – Typical problems with 3D-printing and methods to solve them

| Type of Problem | Description of the Reason |
| --- | --- |
| 1-Not-Extruding-At-Start | * Before printing, the filament was not completely threaded into the extruder; * The nozzle starts to work too close to the substrate; * The filament is unwound against the drive mechanism; * The extruder is clogged. |
| 2-Print-Not-Sticking-To-Bed | * The platform is not horizontal; * The nozzle starts to work too far from the substrate; * The first layer is printed too fast; * Check the temperature or cooling settings; * The problem with the substrate surface. |
| 3-Under-Extruding | * Wrong filament diameter; * Increase the extrusion of the material. |
| 4-Over-Extruding | * Decrease the extrusion of the material. |
| 5-Holes-Or-Gaps-In-Top-Layers | * Insufficient upper solid layers; * The percentage of filling is too low. |
| 6-Hairs-And-Stringing | * Retraction distance; * Retraction speed; * The temperature is too high; * Long movements in open spaces; * Speed of movement. |
| 7-Over-Heating | * Insufficient cooling; * Printing at too high temperature; * Printing speed is too high. |
| 8-Layer-Shifting | * The extruder moves too fast; * Mechanical or electrical problems. |
| 9-Layers-Splitting-Or-Cracking | * The height of the layer is too large; * Printing temperature is too low. |
| 10-Grinding-Or-Stripped-Filament | * Aggressive retraction settings; * Increase of the extruder temperature is needed; * Printing speed is too fast; * Check that the extruder is not clogged. |
| 11-Clogged-Extruder | * Manually insert the filament into the extruder; * Replace the filament; * Clean the nozzle. |
| 12-Stops-Extruding-Mid-Print | * Check existence of the filament; * The filament is wound against the drive mechanism; * The extruder is clogged; * Overheating of the extruder motor. |
| 13-Weak-Or-Stringy-Infill | * Try alternate fill patterns; * Reduce printing speed; * Increase the width of the extrusion of the aggregate. |
| 14-Blobs-And-Zits | * Avoid unnecessary retractions; * Nonstationary retractions; * Select the location of your starting points. |
| 15-Gap-Between-Infill-And-Outline | * Insufficient overlapping of contours in the slicer; * Printing speed is too fast. |
| 16-Curling-And-Warping | * Extrusion temperature is too high. |
| 17-Scars-On-Top-Surface | * Extrusion of too much plastic; * Small vertical rise above the layer (Z-hop). |
| 18-Gaps-In-Floor-Corners | * Insufficient upper solid layers; * The percentage of filling is too low. |
| 19-Lines-On-Side-Of-Print | * • Uncoordinated extrusion; * Temperature changes during printing; * Mechanical problems. |
| 20-Vibrations-And-Ringing | * Printing speed is too fast; * Problems with the acceleration accounting in the firmware; * Mechanical problems. |
| 21-Gaps-In-Thin-Walls | * An error in slicing a thin wall; * Change the width of the extrusion. |
| 22-Small-Features-Disappearing | * Too thin walls in the 3D model; * Install an extruder with a smaller outer diameter. |
| 23-Inconsistent-Extrusion | * The filament accumulates or becomes entangled; * Clogged extruder; * Too low layer height; * Incorrect extrusion width; * Low-quality filament; * Mechanical problems with the extruder. |
| 24-Warping | * Insufficiently heated substrate; * The cooling fan is too powerful. |
| 25-Poor-Surface-Above-Supports | * The height of the layer is too high; * The amount of support is indicated in percentages in the slicer; * Vertical separation layers; * Move the part horizontally. |
| 26-Dimensional-Accuracy-Calipers | * Influence of the first layer; * Re- or under-extrusion; * Constant dimensional error. |

**Additional Information:**

<https://3deshnik.ru/blogs/akdzg/obzor-osnovnyh-nastroek-slajsera-cura>

<http://3dprintingforbeginners.com/troubleshoot-3d-printing-problems/>

<https://simplify3d.com/support/print-quality-troubleshooting/>

<http://support.3dverkstan.se/article/30-getting-better-prints>

<http://support.3dverkstan.se/article/23-a-visual-ultimaker-troubleshooting-guide>

<http://hordaprint.ru/index.php/recommendation>

<https://geektimes.ru/post/253390/>

<http://3dtoday.ru/blogs/garremmash/the-20-most-common-problems-of-3d-printing-part-1/>

<http://3dtoday.ru/blogs/garremmash/the-20-most-common-problems-of-3d-printing-part-2/>

1. **3D scanning and recognition**
   1. ***Principles of 3D Scanners***

3D scanning is the process of automatically collecting and analyzing the data of a real object, namely the shape, color and other characteristics, with the subsequent transformation into a digital three-dimensional model. A 3D-scanned color surface is called a texture.

3D scanning can give a lot of information about the design of an object in a process called reverse engineering.

3D scanners are powerful tools for professionals in several industries, such as automotive, aeronautics, dentistry, jewelry, video games, special effects and animated films.

3D scanning technologies are based on different physical principles and can be classified by the next types:

* **3D scanning with LED backlight.** The main methods of creating models are the creation of laser jammers and projections. The latter uses two flat laser beams to create two equidistant lines. This method is useful for creating an image with almost unlimited depth of sharpness. More common are SL scanners, which operate on the principle of a standard video projector, projecting onto the object a set of alternating black and white bands (see Figure 3.1).

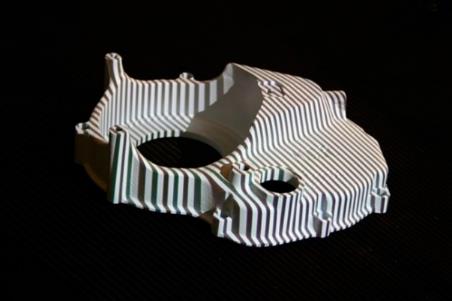


Figure 3.1 – Creating a model with an SL-scanner

* **Laser 3D scanning.** The work is based on different principles: acoustic-optical deflectors, surface-emitting lasers with a vertical cavity, etc. Surface-emitting lasers are used to calibrate the docking on the shuttles that are used by the NASA. Usually laser 3D scanners are used for scanning at long distances, and the principle of operation is similar to that of a laser range finder.
* **Photogrammetry**, also called 3D-scanning from photos. When photographing, several photographs, taken from different angles, are stitched together, reconstructing the 3D model by algorithms of computational geometry.
* **Contact 3D scan.** The scanning tool is a probe that is moved along the surface of the object with the help of a hand or special mechanisms and transmits data about movements to the computer.

**Additional Information:**

<https://make-3d.ru/articles/chto-takoe-3d-skaner-i-kak-on-rabotaet/>

<http://can-touch.ru/blog/vse-o-3d-skanerax/>

<http://3dwiki.ru/3d-scanner/>

<http://robot-ik.ru/articles/kak_rabotaet_ustroystvo_3d_skanerov_tehnologii_i_printsipy_skanirovaniya/>

<http://fotokomok.ru/3d-skanery-princip-raboty-i-primenenie/>

* 1. ***Scanning 3D-objects***

In the process of 3D scanning, a cloud of points is created, noisy with scanner errors and the environment of the object, stored as a *\*.stl* file. By itself, the *\*.stl* file stores information about points and a grid of triangles built on these points. The quality of this model when printing is extremely mediocre, most often without additional processing it is generally unsuitable for printing.

The most common problems during scanning are:

* reverse normals (part of the grid is oriented in the opposite direction);
* open surfaces;
* volumes intersection;
* unbound edges;
* wrong scale.

There are many free programs for restoring models and preparing them for printing , the most famous of which are Meshmixer and Netfabb from Autodesk.

**Additional Information:**

<https://geektimes.ru/company/top3dshop/blog/265626/>

<https://youtube.com/watch?v=bZMSt7bC5qE>

<https://youtube.com/user/netfabb/videos>

<https://youtube.com/watch?v=4VBUcKz2Ids>

<https://youtube.com/user/meshmixer/videos>