
**Technical product documentation —
Requirements for digital mock-up
virtual assembly test for mechanical
products**

*Documentation technique de produits — Exigences sur les essais
d'assemblage virtuel des produits mécaniques*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The digital mock-up virtual assembly test (VAT) is a computer simulation procedure in lieu of performing a physical prototype test for a product to verify the compatibility of the mechanical interface and the feasibility of assembly. This test can be used to explore and resolve interface and/or assembly problems before physical product assembly. VAT activities typically include virtual interference inspection, assembly process analysis and ergonomic evaluation based on 3D nominal models in the design phase. It can be helpful to consider the results of a VAT to predict and provide early warnings regarding the risk of interference or assembly problems, although the VAT cannot completely replace all the tests in on-site assembly testing.

The objectives of the VAT are as follows:

- a) verify the mechanical interface compatibility of units, sub-systems and products;
- b) ensure that the design output is interference-free and that all contacts or clearances are acceptable;
- c) validate layout design at every assembly level;
- d) verify assembly feasibility in the manufacturing and operational environments;
- e) evaluate the assembly process to optimize the assembly plan.

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Technical product documentation — Requirements for digital mock-up virtual assembly test for mechanical products

1 Scope

This document specifies the requirements for a digital mock-up virtual assembly test (VAT) for mechanical products, which is suitable for guiding virtual assembly testing before physical production. The application of this document is intended to result in an effective VAT and efficient on-site assembly. This test is applicable to 3D nominal models with theoretically exact dimensions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 17599, *Technical product documentation (TPD) — General requirements of digital mock-up for mechanical products*

ISO 29845, *Technical product documentation — Document types*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17599 and ISO 29845 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

design model

portion of the data set that contains models and supplemental geometry

[SOURCE: ISO 29845:2011, 3.1.8]

3.2

3D nominal model

type of design model that contains three-dimensional geometry with theoretically exact dimensions

3.3

virtual assembly test

VAT

test for examining an assembly process in a virtual environment

**3.4
simplification**

method which allows some features built without modelling or some parts (or components) without assembling during the modelling process

Note 1 to entry: Through simplification, the geometric detailed representation can be simplified and the model loading efficiency can be improved provided that the simplification does not incur ambiguous understanding or bring about inconvenience to the use of a model.

[SOURCE: ISO 17599:2015, 3.12]

**3.5
lightweight**

method to extract patches from the product geometry model

Note 1 to entry: It reduces resource expenditure in model loading, and it is suitable for large assembly, assembly simulation, advertising, technical training and so on.

[SOURCE: ISO 17599:2015, 3.13]

**3.6
environment model**

type of model containing, for example, shop floor or tools and fixtures

**3.7
ideal human model**

computer-based dummy model in accordance with the actual statistical data set of human body features, typically as a whole-body model or local feature model, inclusive of citizenship or country of residence, gender, height and weight, fatigue and other characteristics

**3.8
process model**

type of model containing an assembly sequence, path and procedure

**3.9
assembly process simulation**

simulation of an assembly process in a virtual environment for the purposes of planning, analysis and optimization

**3.10
assembly path**

movement path of parts or components in an assembly process

**3.11
interference**

parts of two or more 3D nominal models occupying the same space at the same time

**3.12
clearance**

two or more adjacent surfaces in the nominal model not touching one another

**3.13
contact**

two or more surfaces in the nominal model touching one another

4 VAT process

4.1 General principles

A VAT shall be conducted at the design or manufacture start-up phase and shall take into account product peculiarities and complexity; developer and supplier divisions; software and hardware selection; basic library development; test and analysis methodologies; legal restrictions; risk management; cost; schedule; allowable deviations and other constraints. From the unit level through to the integrated product level, the VAT shall be implemented utilizing appropriate technical methods and suitable test tasks shall be performed at each assembly level.

4.2 Workflow process

Generally, the VAT process includes the following preparation, implementation and review phases:

- In the preparation phase, to certify the interface and assembly designs of the product, a VAT plan shall be developed that includes at minimum the test objectives, test tasks, test methodologies, test process, test bill of material (BOM) and test schedule. Test models shall be prepared, including product models, environment models and virtual operator models, and all models shall be certified. A virtual test environment shall be configured and initialized before moving on to the next phase.
- In the implementation phase, an interference inspection and assembly feasibility analysis shall be conducted in a virtual assembly environment. The VAT process and all relevant issues shall be documented, and the results verified in a closed-loop check.
- In the review phase, to validate the test results, a review shall be conducted to establish that the requirements of each of the different phases in the VAT process – preparation, plan, process and report – have been met.

[Figure 1](#) shows a diagram of the VAT workflow process, and [Annex A](#), [Figure A.1](#), shows a VAT aeroplane workflow process.

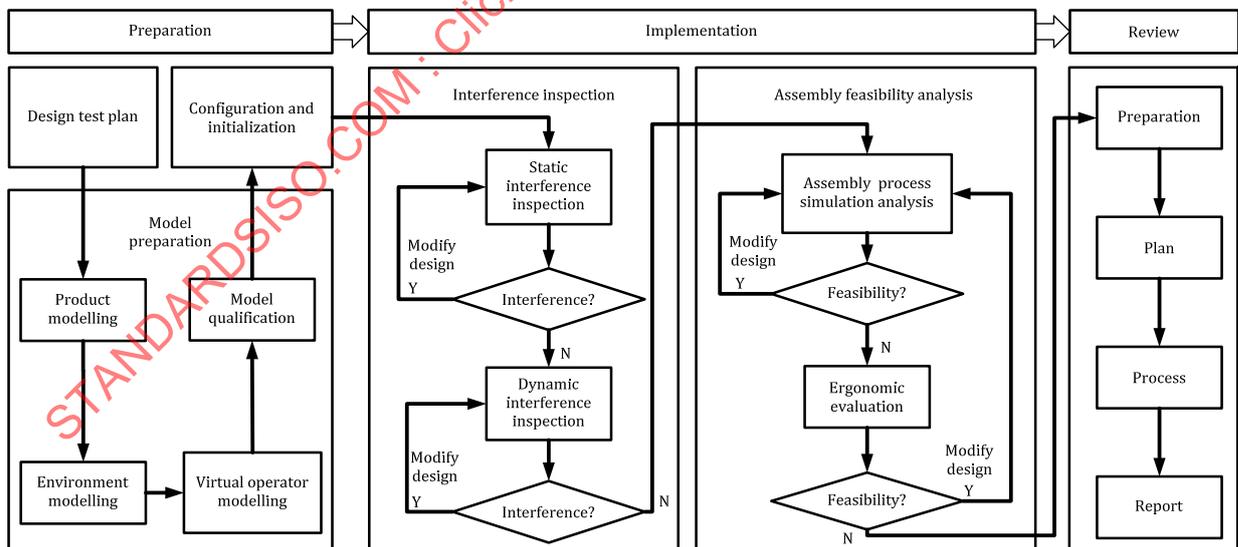


Figure 1 — VAT workflow process

5 VAT preparation requirements

5.1 General

Preparation of a VAT shall comprise the development of a test plan, the preparation of models and the configuration and initialization of a virtual assembly environment. The test plan, models and configuration and initialization statuses shall be documented.

5.2 Test plan

The test plan shall include but not be limited to the following:

- a) Test objectives: specification of test objectives to verify that the design meets the interface and assembly requirements when exposed to applicable environments;
- b) Test tasks: inspection and analysis tasks developed to meet the test objectives, which shall be incrementally performed at different assembly levels from the unit level to the integrated product level;
- c) Test methodologies: a suitable combination of inspection and analysis methods, hardware and software tools and a test process shall be selected or developed to identify latent design defects;
- d) Test process: a detailed flow chart of the VAT steps shall be developed to ensure the validity of the test results;
- e) Test BOM: a complete BOM for the VAT shall be provided according to the test tasks, test methodologies and test process;
- f) Test schedule: a time schedule shall be established to ensure the implementation of the VAT in the appropriate sequence from the unit level to the integrated product level, and the lower-level assembly testing shall be conducted before initiating upper-level testing.

5.3 Model preparation

5.3.1 Product modelling

A product model shall be developed, which may be simplified and/or lightweighted to improve test efficiency without affecting the established test objectives, the details of which are as follows:

- a) The general modelling requirements for mechanical products shall be followed according to ISO 17599.
- b) The simplified and/or lightweighted models at the unit level for the VAT shall keep their external geometric representation and may contain an empty internal chamber.
- c) The simplified and/or lightweighted models at the sub-system level for the VAT shall maintain uniformity of geometry, coordinate information, assembly constraints and other information that serves the test objectives.
- d) The integrated product model shall be partially simplified and/or lightweighted according to the speciality of the test task, without affecting the correct function of the movement mechanism.

5.3.2 Environment modelling

Environment modelling shall be used to hierarchically construct a digital workspace and support facilities that reflect the requirements of the desired assembly activities, as follows:

- a) The shop floor model shall be consistent with the actual workspace, and an activity boundary and operational space shall be established that provide enough assembly space.

- b) Tool and fixture models shall be created according to the actual needs of the assembly activity to verify their practical viability, and the accuracy of the model geometry shall be consistent with that of the product.

5.3.3 Virtual operator modelling

Virtual operator models shall be built on the basis of the ideal human model to accurately reflect the population who will be working in the real operational environment, as follows:

- a) The virtual operator model shall be adjusted in accordance with relevant national standards for the human body that are based on human statistical data from the respective country to ensure that they are sufficient to meet test task requirements.
- b) The virtual operator model shall consider height, weight and fatigue attributes of the ideal virtual human model as the minimum number of working characteristics to meet simulation and analysis requirements.

5.3.4 Model qualification

Model qualification shall focus on the completeness, conformity and integration of models, as follows:

- a) Completeness of models is in accordance with the test BOM.
- b) Conformity of models is in accordance with the test plan.
- c) Integration of models is in accordance with the modelling requirements, which shall include but not be limited to the software version, templates, coordinate system definition, units of measurement, quality, and colouring and labelling.

5.4 Configuration and initialization

Hardware and software shall be configured and initialized for VAT implementation. It is essential that appropriate parameters be set to ensure the best VAT performance. Configuration and initialization shall be defined by but not be limited to the following:

- a) The hardware configuration shall establish and display the running memory capacity.
- b) The software configuration shall customize the frequency of automatic backup, display precision, graphic cache management, units of measurement, toolbar and user interface.
- c) Assembly initialization shall establish a unified assembly datum, build structure tree and assembly sequence, layout position and record of the initial state.
- d) Product model initialization shall include the establishment of the assembly hierarchy, assembly relationship, layout and positions.
- e) Environment model initialization shall consist of lightweight settings, hidden simplifications, and transparent settings for fixtures, tools and factory buildings.
- f) Operator model initialization shall consist of the initial posture and position coordinates.

6 VAT implementation requirements

6.1 General

VAT implementation shall comprise interference inspection and assembly feasibility analysis. Tasks related to interference inspection generally include static and dynamic interference inspections, whereas tasks related to assembly feasibility analysis generally include assembly process analyses and ergonomics evaluation.

6.2 Interference inspection

6.2.1 Inspection tasks

Interference inspection is performed to analyse the latent interference problems of components on the assembly path. For a small and simple product, many interferences may be identified by manual observation. However, for a complex product, appropriate tools and a suitable process shall be established to identify problems. Generally, there are two types of interference inspection tasks: inspection of possible interference between parts in a product or between fixtures and the product.

Inspection tasks to identify latent interference problems between parts in a product typically involve but are not limited to the following parts:

- a) connecting holes and bolts between interfaces;
- b) flange step surfaces and seals;
- c) tubes and associated flanges;
- d) tubes and their structural supports;
- e) instruments and their structural supports;
- f) electric plugs and sockets and their structural supports;
- g) wires and their structural supports;
- h) moving mechanism parts.

Inspection tasks to identify latent interference problems between fixtures and a product typically involve but are not limited to the following fixtures:

- 1) riveting structure support;
- 2) welding structure support;
- 3) docking fixtures;
- 4) support vehicles;
- 5) transport vehicles;
- 6) packing boxes.

6.2.2 Static interference inspection

6.2.2.1 Process

The static interference inspection process of a VAT is generally as follows:

- a) Select a static interference inspection task for parts of the product and/or fixtures.
- b) Define the pass-fail criteria of the static interference inspection according to the design requirements.
- c) Verify all relative models of the product and/or fixtures.
- d) Perform static inspection analysis by automatic and/or manual methods.
- e) Record contact, interference and clearance results.
- f) Collate and analyse discrepancies between the results and the design requirements.

g) Draft a static interference inspection report.

Figure 2 shows the workflow process of static interference inspection.

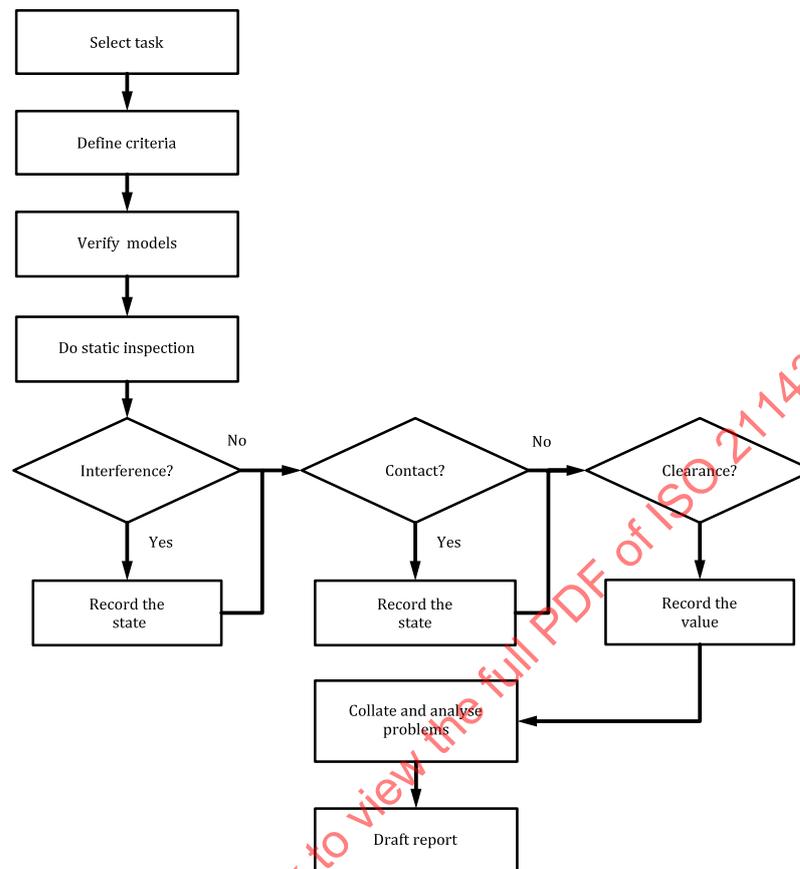


Figure 2 — Workflow process of static interference inspection

6.2.2.2 Methods

Static interface inspection generally involves automatic inspection, manual inspection or some combination of the two, as follows:

- Automatic inspection involves the application of interference inspection software that automatically calculates the interference, and usually applies algorithms related to space decomposition, hierarchical bounding volumes and Boolean intersection.
- Manual inspection involves the adjustment of the model to an appropriate perspective through manual rotation in different directions and zooming in or out, followed by observing the interference and measuring the clearance and interference value.
- Both automatic and manual inspections are generally performed according to the product assembly sequence. When the objects of automatic inspection contain a lightweight model, manual inspection should be used.
- Manual inspection shall be used to address other concerns not involving interference, including misaligned holes or flanges, incorrect tie-downs of tubing/wiring, defective seals, unsuitable pin lengths and incompatible connectors or fixtures.

6.2.3 Dynamic interference inspection

6.2.3.1 Process

The dynamic interference inspection process of a VAT generally proceeds as follows:

- a) Select a dynamic inspection task for the parts of a product and/or fixtures.
- b) Define pass-fail criteria for the dynamic interference inspection according to the design requirements, such as kinematic boundaries or clearance qualification.
- c) Verify the inputs, which generally include motion conditions and all relative models.
- d) Create a movement mechanism, including moving pairs and fixed parts, and then verify the correctness of the degrees of freedom and movement limit.
- e) Define motion equations in accordance with the test task.
- f) Set the motion to run for more than one cycle and create a motion track.
- g) Hide all unnecessary datum planes, points, sketches and other modelling features.
- h) Perform dynamic inspection by automatic and/or manual methods.
- i) Record contact, interference and clearance results.
- j) Plot a distance curve with respect to time to obtain a graphical representation.
- k) Record motion process and save a motion video of at least one cycle.
- l) Collate and analyse discrepancies between the results and design requirements.
- m) Draft a dynamic interference inspection report.

Figure 3 shows the workflow process for dynamic interference inspection.

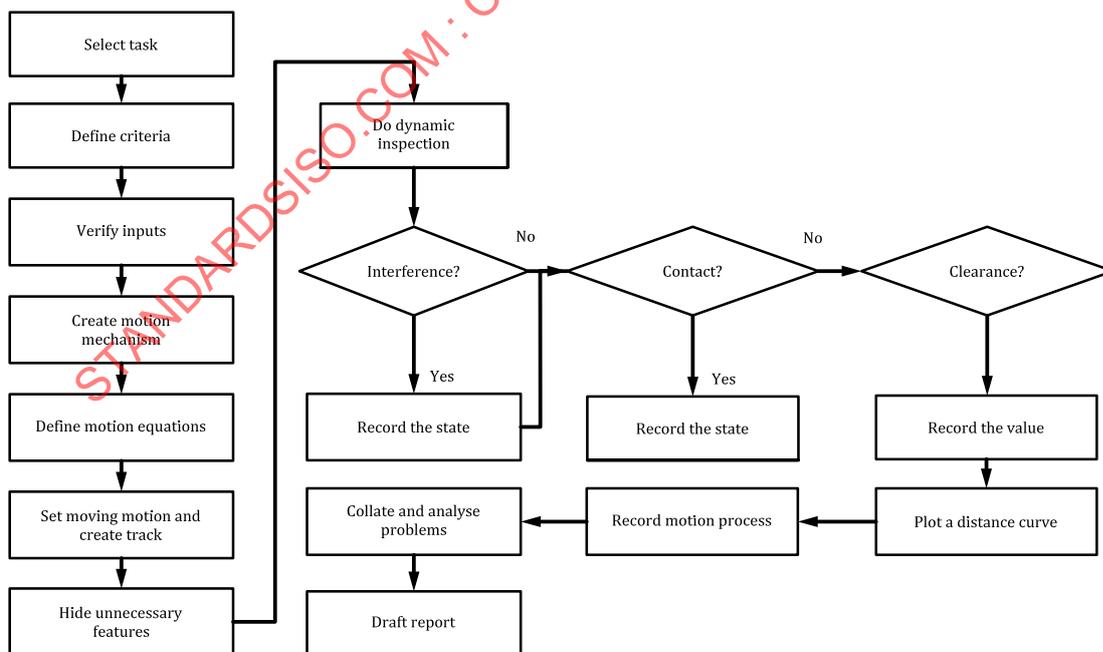


Figure 3 — Workflow process of dynamic interference inspection

6.2.3.2 Methods

Dynamic interference inspection is generally conducted manually, and is then supplemented by automatic inspection, the details of which are as follows:

- a) There are two ways to conduct a manual inspection: manually identifying key objects then taking and recording spacing measurements; or generating and assembling a motion envelope with respect to the original system, then converting a dynamic inspection into a static inspection.
- b) Automatic inspection utilizes interference inspection software to calculate the interference, and a static inspection is performed at each time step during the motion process.
- c) The objects of dynamic interference inspection should be the structural or mechanism parts that have only a small clearance or moving parts characterized by interference risks.
- d) The frequency of motion should be set according to the test purpose, taking into consideration the operation time and motion fluency.

6.3 Assembly feasibility analysis

6.3.1 Analysis tasks

Assembly feasibility analysis is a simulation process that shall be applied to product parts or components when assembly space is tight or the assembly process is complex. If the assembly and disassembly processes have a corresponding sequence, the installation process shall be selected as the major process for the analysis of assembly feasibility. Ergonomics evaluation is conducted using a bottom-up approach in the product according to the predefined assembly plan. The predefined assembly sequence and path plan are optimized by iterative simulation of the ergonomics evaluation until the criteria are met.

The analysis tasks of the assembly process generally involve but are not limited to the following product parts:

- a) shaft, rod and plate parts;
- b) cabin components and structural modules;
- c) instrument and equipment;
- d) tubes and wires;
- e) mechanisms.

For products with an extremely narrow or tight operational space, tube or wire installation operability analysis shall take into consideration the tube or wire bending margin and the heat-resistant or waterproof surface coating envelope.

Ergonomics evaluation tasks generally consider:

- 1) human reachability;
- 2) human visibility;
- 3) human comfort;
- 4) other factors.

Fastener installation and torque operation simulations shall be established to analyse the safety clearance in cases where the assembly space is tight.

Supplemental fixture requirements may be added based on the results of a VAT according to the actions of a virtual operator with respect to, for example, a pedal or ladder.

6.3.2 Assembly process analysis

6.3.2.1 Process

The virtual assembly process analysis generally proceeds as follows:

- a) Select a task for the analysis of an assembly process.
- b) Define pass–failure criteria for the analysis, which shall include an optimal assembly path, best assembly sequence and optimization of assembly process.
- c) Build a process model according to the product installation, operation and reverse assembly processes.
- d) Set the initial assembly sequence and initial path of movement according to the predefined assembly operation sequence, from the starting point to the destination.
- e) Simulate the assembly process based on the initial assembly sequence and initial path of movement.
- f) Check for interference and fitting problems during the assembly process simulation.
- g) Adjust assembly sequence or assembly path until the interference problems and fitting problems are completely resolved.
- h) Determine whether the process is optimal.
- i) If not, adjust the assembly sequence or assembly path until the process is acceptable.
- j) Repeat steps c) to i) until a reasonable assembly process is achieved.

Figure 4 shows the workflow of assembly process analysis.

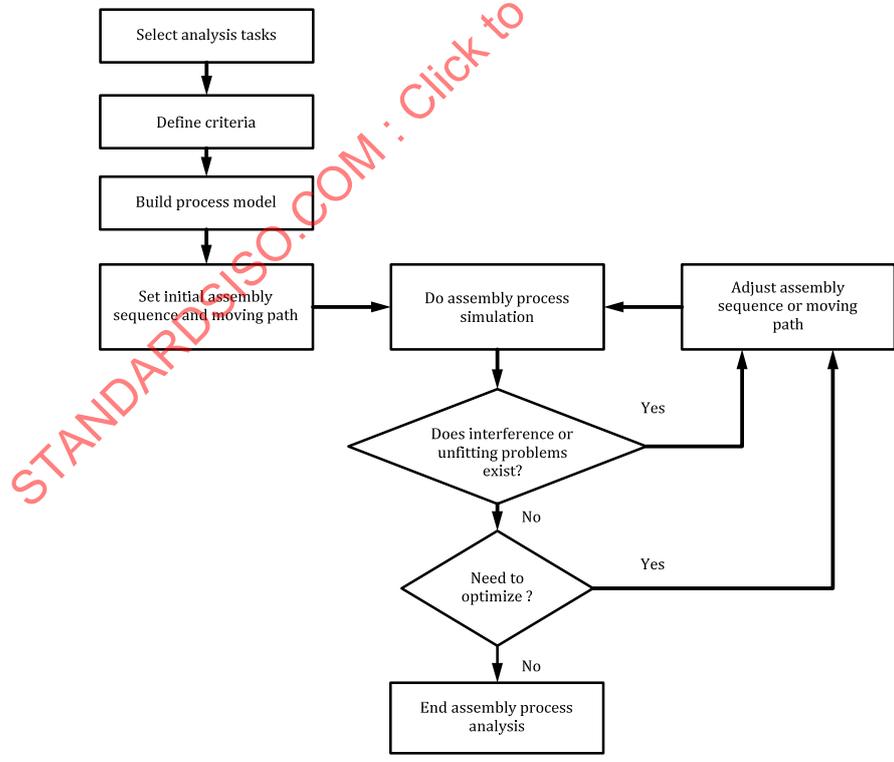


Figure 4 — Workflow of assembly process analysis

6.3.2.2 Methods

The methods employed in a virtual assembly process analysis should generally be as follows:

- a) Use simulation software for the assembly process analysis of process planning and optimization.
- b) Assembly planning shall generally be performed by a combination of automatic and manual methods.
- c) The automatic planning process should first apply a simulation tool to calculate a reasonable path according to the proposed assembly sequence.
- d) Manual planning should involve observation of the assembly space, and repeated adjustments to the predefined path to realize a better outcome.
- e) When there is inflexibility or an open space in the assembly, the application of automatic planning is suitable.
- f) For the appropriate methods to use to check for interference in an assembly process, refer to [6.2.2.2](#) and [6.2.3.2](#).

6.3.3 Ergonomics evaluation

6.3.3.1 Process

The ergonomics evaluation process is as follows:

- a) Select tasks for evaluation.
- b) Define pass-failure criteria for the ergonomics evaluation according to the design requirements.
- c) Initiate a simulation environment and process status according to the assembly sequence and assembly path set-up described in [6.3.2](#).
- d) Add a virtual operator model to the process and set up the initial posture.
- e) Connect a virtual operator action to the assembly path and perform sequential assembly process simulations based on segmented nodes of the assembly path.
- f) If interference occurs in the assembly process, improve the related design and redefine the assembly process and path.
- g) After resolving the interference problems, adjust the related operator posture and repeat the simulation to check the visibility, accessibility and human comfort factors.
- h) Assembly process planning and ergonomics assessment can be performed simultaneously and repeatedly until a reasonable assembly process or a determination regarding its infeasibility is obtained.

[Figure 5](#) shows the workflow process of the ergonomics evaluation.