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Digital validation by effective use of simulation

Validation numérique par utilisation efficace de la simulation

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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

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

Introduction

Precision and high-performance electrical products can be defined as products that integrate mechanical, electrical/electronic, and software technologies. These digitally integrated products are expected to simultaneously achieve high functionality and low cost. In order to meet these needs, computer technology, which enables designing of highly functional products in a limited period of time, is necessary. Effective measures to realise such design can include active use of computer simulations from the functional design stage upstream of a design process, evaluating aspects of the feasibility of the expected function, and narrowing the appropriate design solutions at an early stage.

This document examines the business requirements for using simulation in the functional design process and identifies the key technical capabilities needed to satisfy those requirements. Based on a comparison with the capabilities of current technologies validated through research and experimental examples, this document identifies a number of digital validation technologies which need to be developed in order to meet future business needs, and the associated standardization requirements.

Digital validation by effective use of simulation

1 Scope

This document examines the standardization requirements for the necessary digital validation technology for improving design efficiency by effectively utilizing simulation data at the functional design stage of digitally integrated products.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
digitally integrated product
precision and high-performance product that integrates mechanical, electrical/electronic, and software technologies

3.1.2
model-based development
MBD
mathematical and visual method of addressing problems associated with designing complex control-, signal-processing and communication systems

3.1.3
functional mock-up interface
FMI
standardized interface used in computer simulations to develop complex cyber-physical systems

Note 1 to entry: See FMI version in Reference [3].

3.1.4
functional mock-up unit
FMU
component that implements the *functional mock-up interface* (3.1.3)

3.1.5
co-simulation
two or more simulation functions interacting to simulate different aspects of a digitally integrated product

3.1.6
simulation time interval
Δt
simulation time step size in a dynamic simulation

3.1.7
supplier
manufacturer that supplies parts to *original equipment manufacturers* (3.1.8)

3.1.8
original equipment manufacturer
OEM
company that manufactures finished or semi-finished products to be sold by another manufacturer

3.1.9
machine-readable data
data in a format that can be automatically read and processed by a computer

Note 1 to entry: Machine-readable data shall be structured data.

3.1.10
human-readable data
encoding of data or information that can be naturally read by humans

Note 1 to entry: In computing, human-readable data is often encoded as ASCII or Unicode text, rather than as binary data.

3.1.11
reduced order model
ROM
mathematical model with reduced complexity for use in digital simulations

3.1.12
finite element analysis
method for solving problems of engineering and mathematical models

3.1.13
1D CAE
multi-domain systems simulation combined with controls

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply:

CAD computer aided design

CAE computer aided engineering

3.3 Trademarks

For the purposes of this document, the following trademarks are used. The reason that these trademarks have been used in this document is given in the footnotes.

Modelica®[1]: An object-oriented, declarative, multi-domain modelling language for component-oriented modelling of complex systems, e.g. systems containing mechanical, electrical, electronic, hydraulic, thermal, control, electric power or process-oriented subcomponents.

1) This trademark is provided for reasons of public interest or public safety. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC. Modelica® is a registered trademark of the Modelica Association.

MATLAB®[2]: A proprietary multi-paradigm programming language and numerical computing environment.

Simulink®[3]: A MATLAB-based graphical programming environment for modelling, simulating and analysing multi-domain dynamical systems.

SystemC™[4]: A type of hardware description language (HDL) intended for use in functional design of electronic circuit equipment.

ANSYS® Maxwell®[5]: A type of industry electromagnetic field simulation software for the design and analysis of electric motors, actuators, sensors, transformers and other electromagnetic and electromechanical devices.

ANSYS® RMxprt™[6]: A template-based design tool that designers of electrical machines and generators can use to enhance ANSYS Maxwell.

ANSYS® Twin Builder™[7]: An open solution that allows engineers to create simulation-based digital twins–digital representations of assets with real-world or virtual sensor inputs.

4 Business case for computer simulation in early design stage

Precision and high-performance electrical products, e.g. multifunctional copiers, printers, digital cameras, and automated teller machines (ATMs) can be recognized as examples of products that integrate mechanical, electrical/electronic, and software technologies. These digitally integrated products have to achieve high functionality, rapid development and low costs simultaneously, therefore, computer technology which enables designing of such highly functional products in a limited period of time is a key business demand. Effective measures to realise such designs can include actively utilizing computer simulations from the functional design stage upstream of a design process, evaluating the feasibility of the expected function, and narrowing the appropriate design solutions at an early stage [1,2].

These measures are common in a broad range of the manufacturing industry.

5 Major challenges in simulation

Figure 1 shows a typical design process of a digitally integrated product. The blue arrow in the figure indicates the software development process; the yellow and green arrows indicate the mechanical and electrical development processes, respectively. The arrow in the top section of the figure indicates the process where a part of the design work may be contracted to external collaborating companies.

2) This trademark is provided for reasons of public interest or public safety. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC. MATLAB® is a registered trademark of The MathWorks®, Inc.

3) This trademark is provided for reasons of public interest or public safety. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC. Simulink® is a registered trademark of The MathWorks®, Inc.

4) This trademark is provided for reasons of public interest or public safety. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC. SystemC™ is a trademark of Accellera Systems Initiative Inc.

5) ANSYS® Maxwell® is the of a product supplied by ANSYS. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

6) ANSYS® RMxprt™ is the trademark of a product supplied by ANSYS. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

7) ANSYS® Twin Builder™ is the trademark of a product supplied by ANSYS. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

The product specification is determined first, followed by the definition of the basic product system and architecture. Subsequently, the design process is classified into software, mechanical design, and electrical design workstreams. Further, functional design, detailed design, and performance design are conducted in that order in each workstream. Though the work is generally conducted independently in each workstream, information exchange is often carried out across the boundary of the workstreams and enterprises as necessary.

Various tests and trials are conducted, and the product functionality is confirmed during the performance evaluation stage. If problems are identified in this stage, information regarding the problems is fed back to the detailed design stage and design changes are executed to resolve the problems. In cases with serious problems, it can be necessary to return to the functional design stage and restart the work, which can result in large losses in cost and time. Prototyping and testing are conducted once performance evaluation is successfully completed and production is initiated after manufacturing preparation.

The EN/NAS 9300 series and sub referenced ISO 10303 series can be useful for manipulating design feedback.

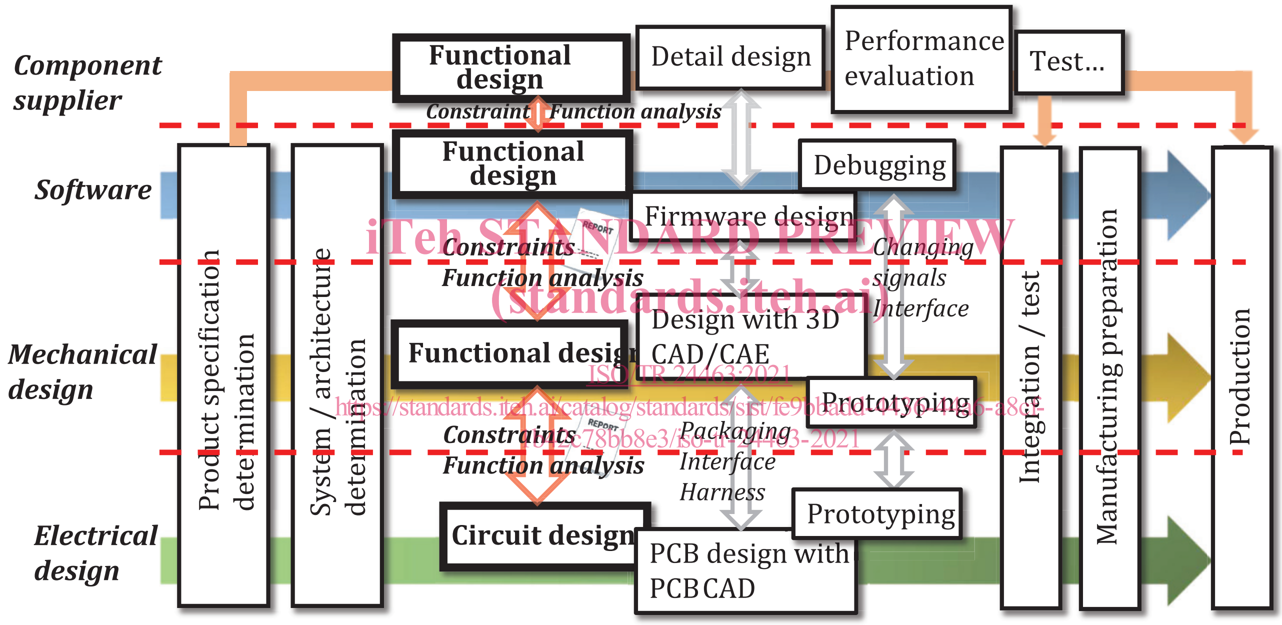

Figure 1 — Typical design process of the digitally integrated product

To achieve high functionality and low cost simultaneously, it is important to thoroughly conduct parallel computer simulations at the functional design stage upstream of the design process, to verify the design and reduce functional uncertainty as much as possible, and to reduce the possibility of cases where problems are detected downstream of the design process which would require rework of the product design.

Most geometric information related to the product is not determined at the initial functional design stage. Since many existing computer simulation or computer aided engineering (CAE) technologies are based on the shape information of the product, they are difficult to use in the verification work in such an early stage of the design. Some advanced companies have coped with these types of problems in their CAE software by developing their own simulation tools, but often their own design knowledge is embedded in proprietary software. This precludes independence from a specific toolset and constrains long-term maintenance and development.

Decisions in the upstream design are generally transmitted in the form of documents to the downstream processes. Therefore, the mechanism to reflect functional design results in the detailed design often depends on the interpretation of an individual designer, so neither uncertainty nor ambiguity can be removed. Currently, information exchange between different workstreams and enterprises is usually carried out through documents, and similar problems are unavoidable.

Based on these issues, the following requirements have been identified for digital validation technologies ensuring the effective application of simulations at the functional design stage.

a) Simulations without geometric information

   Simulations that do not require geometric information of the product are required to support functional design. These 1D CAE technologies, which are widely used in automobile and aircraft production, are considered a prime candidate for this type of simulation.

b) Co-simulation of different technical domains

   Functional verification of digitally integrated products requires technology that can evaluate phenomena in different technological domains, e.g. mechanical, electrical/electronic, and software, simultaneously and in parallel, i.e. technologies that can handle multiple simulations in different technical domains while considering interaction between them.

c) Simulations connected to 3D CAD/CAE

   There are 3D CAD models that have been developed based on functional design and detailed functional analyses have been conducted using 3D CAE. Currently, designers manually convert functional design results into 3D models. According to analysis results of 3D CAE, rework of functional design may be required. At present, the work which reflects the result of this 3D CAE back to the functional design is also carried out manually.

d) Simulations for collaborative design with multiple companies

   Many digitally integrated products are developed by the collaborative work of multiple workstreams within companies. Recently, the number of joint product developments by multiple companies is increasing. It is necessary to have a mechanism for sharing not only the relevant model data used in the simulation but also various technical information on the model beyond the boundary of the workstreams and enterprises.

This document describes the various components of digital validation technology that extend existing 1D CAE capabilities to satisfy these four requirements.

6 Digital validation technology

6.1 State of the art

Effective measures for increased performance, realisation of required complexity and reduced cost are common requirements in all manufacturing industries, and various solutions have been implemented to satisfy the requirements. Model-based development (MBD) has shown some success in the fields of automobile and aircraft production. MBD describes product function and design requirements as numerical models (often as ordinary differential equations) and conducts functional analysis/verification by solving the resulting numerical models. Functional analysis is possible even with incomplete geometric information of the product if differential equations are defined using this method; therefore, this method is suitable for use in the upstream design process. The use of MBD in the functional design process is often referred to as 1D CAE. Modelica and MATLAB/Simulink, which are examples of 1D CAE tools, have already been developed and applied in automobile design and aircraft design.

Multiple functionally common components are used for representing mechanical or electrical products. For example, many mechanical products use coupling, power transmission, power control, fluid transmission, and lubrication elements. Numerical models that correspond to two or more of these functional elements are packaged together and supplied as a library in the 1D CAE tool environment. A designer can select functional elements from a library and model product functions by connecting elements on a screen with a graphical editor, in order to simulate its behaviour. Common approaches include creating more complex elements by combining basic functional elements or distributing them as libraries by packaging these elements.

The use of 1D CAE is believed to be effective in the functional design support of digitally integrated products, if the following three digital validation technology functions can be provided.

a) In mechanical, electrical/electronic, and software domains, 1D CAE technologies suited for each domain are already widespread. Thus, it is important to create an interface function for activating multiple 1D CAE tools in parallel to achieve coupled simulations for different technical domains. It is believed that a functional mock-up interface/unit (FMI/FMU) is effective to achieve this type of interface.

b) The 1D CAE models obtained from the functional design results are refined into a 3D CAD model and used in high-accuracy functional analysis with 3D CAE. The functional design may need to be reworked based on the 3D CAE analysis results, and therefore, the ability to update the 1D CAE model based on the 3D CAD/CAE results is also important. An interface for this type of model conversion between 1D CAE and 3D CAD/CAE is necessary.

c) An interface which enables exchange of 1D CAE models and accompanying technical information between different workstreams and companies is required. Information exchange between different workstreams and companies are repeated as the design progresses, and the information is continuously revised along this process. A function that can suitably record this type of process and consistently manage the technical information accompanying the models is also required.

The next subclauses explore the state of the art in these technologies, using existing tools, and use examples to illustrate the new capabilities that are required.

6.2 1D CAE modelling of digitally integrated products

6.2.1 Introduction to example

1D CAE technology enables evaluation of design ideas at a stage where geometric information of the product is not yet determined. This satisfies the first requirement of the use of simulations in the functional design process of digitally integrated products. The effectiveness of 1D CAE in the functional design process can be demonstrated by an example of modelling and analysis of the behaviours of belt conveyor and heat roll mechanisms that simulate the paper conveyor mechanism and image fixing unit of a plain paper copying machine (copier), which is a typical digitally integrated product. The former is referred to as "mechanism analysis", the latter, as "thermal system analysis". These examples show that two completely different physical phenomena can be modelled using the same 1D CAE technology.

1D CAE is not yet supported by the ISO 10303 series. Such support would require a thorough integration with existing ISO 10303 parts to make it part of the comprehensive product lifecycle model of STEP. In order to support exchange, sharing and archival of 1D CAE data and their validation, the integrated resources of the ISO 10303 series need to be extended. This needs to be carried out in a consistent manner by following the current methodology and by extending existing and/or developing new documents. ISO 10303-209, ISO 10303-210, ISO 10303-235, ISO 10303-242 and ISO 10303-243[8] include the new capabilities to offer them in an integrated manner to the industrial user.

6.2.2 Belt conveyor mechanism

Figure 2 shows the mechanism that conveys media such as paper using a belt. This mechanism is comprised of a belt transfer mechanism, a motor driving mechanism that applies a driving force to the belt, and a mechanism for controlling the motor by detecting the position of the medium by a light-blocking sensor. The belt conveyor mechanism can be viewed as a mechanical system; the motor driving mechanism, an electric system; and the motor control system, a software system. In the functional design of this belt conveyor mechanism, it is necessary to determine the sensor position to satisfy the

8) Under preparation. Stage at the time of publication: ISO/DIS 10303-243:2021.

