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AI Cutting Machine Classification White Paper

White Paper on the Hierarchical System for AI Cutting Machines

This white paper presents Bodor Laser's recommended AI cutting machine classification system.
It is intended as a technical reference and does not constitute a mandatory standard or third-party certification.

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1 Overview

1.1 Background

Driven by artificial intelligence, large language models, machine vision, and autonomous decision-making technologies, laser cutting equipment is moving from automation toward intelligent operation. However, as the industry develops rapidly, it also faces conceptual ambiguity and inconsistent terminology. Terms such as AI cutting, intelligent cutting, and unmanned cutting overlap in everyday use, making it difficult for users to compare equipment objectively.

Functions such as automatic edge finding, process parameter recommendation, and visual recognition are often marketed as AI cutting. Yet there is no unified classification benchmark connecting individual functions with overall machine capability. As a result, customers lack a credible basis for purchasing decisions and technology evaluation.

This white paper proposes a definition of an AI Cutting Machine and establishes an L0-L5 six-level classification system. It aims to provide a shared technical language, an objective evaluation scale, and a clear roadmap for technology development across the cutting industry.

1.2 Purpose

Establish a classification system for AI cutting machines.

Clarify the definition and core capabilities of AI cutting machines.

Build an operable evaluation framework.

Guide orderly industry development and innovation.

1.3 Scope of Application

This classification system applies to AI cutting equipment including flat-sheet, tube, profile, sheet-and-tube integrated, and 3D five-axis cutting machines using laser, plasma, flame, or waterjet processes. It does not apply to hand-held cutting tools or light-duty craft cutting equipment such as apparel and paper cutting devices.

1.4 One-Page Classification Table

Level	Decision Owner	Key Characteristics	Typical Scenarios and Functions
L0 No Cutting Intelligence	Human	All operations rely on manual work.	Manual loading, material positioning, process setup, processing, quality confirmation, exception handling, and unloading, such as manual centering, manual or automatic focusing, and manual process adjustment.
L1 Cutting Assistance	Human	The system assists with one or more tasks.	The machine provides selected intelligent-assist functions such as AI customer service, active collision avoidance, fast centering, maintenance reminders, and edge-crossing protection. The cutting workflow and quality remain operator-owned.
L2 Partial Cutting Intelligence	Human	The system provides decision support.	The machine provides decision recommendations such as AI fault diagnosis, AI process parameter recommendations, and equipment life prediction. After operator confirmation, selected processing steps can be optimized automatically.
L3 Conditional Cutting Intelligence	System (specific conditions)	Under defined scenarios, the system autonomously completes part of the decisions.	In defined scenarios, the machine can independently decide and execute cutting rollback, adapt to material conditions, adjust cutting speed, and complete batch processing.
L4 High-Level Cutting Intelligence	System	Under defined scenarios, the system autonomously completes all decisions.	In defined scenarios, embodied intelligent equipment can replace human operation and enable automatic loading, material recognition, nesting, dynamic process optimization, efficiency optimization, and automatic unloading.
L5 Full Cutting Intelligence	System	Across all scenarios, the system autonomously completes all decisions.	Across all scenarios, the machine works with embodied intelligence to complete perception, analysis, decision-making, execution, and optimization without human participation across the full production lifecycle.

L2 is the entry threshold for an AI cutting machine under this framework. The proposed classification system is a reference framework developed by Bodor Laser based on industry experience and technical understanding, intended to provide a common language for technical discussion.

2 Why a Classification System Is Needed

2.1 What Is an AI Cutting Machine?

> Key point: An AI Cutting Machine integrates artificial intelligence into cutting operations and forms an intelligent closed loop of perception, analysis, decision-making, execution, and optimization. Under this framework, it must reach L2 or above.

These five capabilities form a complete intelligent loop: perception collects equipment, material, and process information; analysis interprets process status and detects abnormalities; decision-making generates process strategies; execution completes the required motion and processing actions; optimization continuously improves parameters, path planning, and maintenance strategies based on results and historical data.

A machine must meet two necessary conditions: it must have the five core capabilities as a data loop, and its automation level must reach L2 or above. Equipment at L0 or L1 may include isolated intelligent modules, but it is not considered an AI cutting machine under this framework.

2.2 AI vs. Automation

> Key point: Automation solves how to execute. AI solves how to decide.

Dimension	Automated Equipment	AI Cutting Machine
Operating mechanism	Completes processing tasks automatically according to preset rules.	Analyzes real-time status, generates decisions, and continuously optimizes.
Adaptability	Follows fixed rules and cannot handle unforeseen condition changes.	Adjusts in real time based on material status, equipment status, and cutting quality.
Learning ability	None; rules must be updated manually.	Learns and optimizes continuously based on historical data and processing results.
Typical example	Code-driven motion execution.	Real-time process analysis, speed adjustment, and quality optimization.

2.3 Why Not Every Intelligent Function Counts as AI?

Take active collision avoidance as an example. It can perceive and execute, and may include basic analysis, but it lacks decision-making and optimization. Therefore, it is an assistive function rather than a complete AI cutting capability.

Capability	Does active collision avoidance have it?
Perception	Yes - detects material position
Execution	Yes - drives motors to adjust head position
Analysis	Basic analysis only
Decision-making	No
Optimization	No

2.4 Why Does AI Start at L2?

Level	Name	Does AI participate in cutting decisions?	Can it be called an AI cutting machine?
L0	No Cutting Intelligence	No	No
L1	Cutting Assistance	No - only assistive execution, no decisions	No
L2	Partial Cutting Intelligence	Yes - the system provides decision recommendations	Yes
L3	Conditional Cutting Intelligence	Yes	Yes
L4	High-Level Cutting Intelligence	Yes	Yes
L5	Full Cutting Intelligence	Yes	Yes

L2 is the entry-level descriptive threshold for an AI cutting machine within this classification framework.

2.5 What Problems Does the Classification System Solve?

The cutting industry is undergoing an evolution toward intelligence, but it faces a fundamental market mismatch: suppliers and users lack a shared language for evaluating technical capability.

For equipment manufacturers, the system provides a capability roadmap: which functions belong to L2, which belong to L3, and what must be added to move from L2 to L3. Without a shared reference, different manufacturers describe AI functions differently and R&D; direction can become fragmented.

For end users, the system creates a basis for comparing equipment capability and making more rational purchasing decisions. It also helps distinguish whether cutting quality deviations are caused by operator decisions or system-level autonomous decisions.

For the overall industry, the system turns AI cutting from a vague label into a technical capability scale. Its mechanism is comparable in spirit to SAE J3016 for driving automation and GB/T 40429 for intelligent connected vehicles: it does not replace underlying technical standards, but provides a general coordinate system for technical discussion.

3 Five Core Capabilities of AI Cutting Machines

3.1 Capability Overview

Core Capability	Definition	Typical Functions
Perception	Collects equipment, workpiece, and process status information through multiple sensors.	Material recognition, defect detection, weld seam recognition, slag monitoring, edge positioning, process positioning, height sensing, safety sensing.
Analysis	Uses rule engines, knowledge bases, and models to understand and analyze perception data.	Process parameter analysis, cutting quality assessment, fault diagnosis, life prediction, risk assessment.
Decision-making	Generates optimized processing strategies according to targets and real-time status.	Parameter recommendation, path optimization, automatic cutting decisions, equipment maintenance decisions.
Execution	Completes physical actions required by the cutting task.	Automatic focusing, edge finding, centering, cutting, loading and unloading coordination, nozzle changing, adaptive parameter adjustment.
Optimization	Continuously improves processing based on historical data and results.	Adaptive process adjustment, cutting effect optimization, efficiency optimization, yield optimization, energy-consumption optimization.

3.2 Closed-Loop Operation of the Five Capabilities

Perception -> analysis -> decision-making -> execution -> optimization. Optimization results feed into the next round of perception and decision parameters, forming a complete AI cutting closed loop. Only when these five capabilities are present together, even at different maturity levels, can true intelligent cutting be achieved.

4 AI Cutting Machine Classification Definitions

4.1 Basic Principle

> Key point: A higher level must cover the main characteristics of all lower levels. Levels cannot be skipped.

If a machine or module achieves a high-level feature, such as L3, but does not meet lower-level requirements, such as L2, it cannot be classified at the higher level.

4.2 Level Overview

Level	Name	English	Decision Owner
L0	No Cutting Intelligence	No Cutting Intelligence	Human
L1	Cutting Assistance	Cutting Assistance	Human
L2	Partial Cutting Intelligence	Partial Cutting Intelligence	Human
L3	Conditional Cutting Intelligence	Conditional Cutting Intelligence	System under specific conditions
L4	High Cutting Intelligence	High Cutting Intelligence	System
L5	Full Cutting Intelligence	Full Cutting Intelligence	System

4.3 Detailed Definitions

L0 - No Cutting Intelligence

All operations rely on human labor. The machine is only an energy output tool under manual control, with no AI perception, decision-making, or learning capability.

Level	Perception	Analysis	Decision	Execution	Optimization
L0	No	No	No	No	No
L1	Single-point	Basic	No	Assistive	No

L1 - Cutting Assistance

The machine provides one or more assistive functions. The system can assist with individual tasks, but humans remain responsible for all decisions and cutting quality.

L2 - Partial Cutting Intelligence - entry threshold for AI

> Key point: Starting from L2, the system provides intelligent decision recommendations for the first time. AI participates in the cutting decision process.

The system provides decision recommendations, while operators confirm the final decision before execution. Some processing steps can be optimized automatically. Typical functions include AI fault diagnosis, AI process parameter recommendations, equipment life prediction, weld seam recognition, real-time centering, and beam centering.

L3 - Conditional Cutting Intelligence

Under defined scenarios, the system autonomously completes part of the decisions and executes dynamic cutting tasks, enabling batch processing. Operators become backup users and intervene when the system requests handover or exceeds the operating boundary.

L4 - High Cutting Intelligence

Under defined scenarios, the system autonomously completes all decisions and uses embodied intelligence to replace human operation, enabling fully automatic operation of the production workflow. If the machine exceeds its operating boundary, it automatically enters a minimum-risk state and issues an alarm.

Capability	Perception	Analysis	Decision	Execution	Optimization
L2	Multi-source perception	Basic analysis	Decision recommendation	Linked execution	Conditional proactive optimization
L3	Real-time multi-status	Deep analysis	Autonomous partial decision	Fully automatic execution	Conditional proactive optimization
L4	Full-domain multi-status	Deep analysis + prediction	Full autonomous decisions	Full automatic + self-compensation	Closed-loop optimization
L5	Full-domain full-status	Cognitive-level analysis	Scenario-wide autonomy	All-condition adaptation	Self-evolution

L5 - Full Cutting Intelligence

The system autonomously completes the closed loop of perception, analysis, decision-making, execution, and optimization across all application scenarios, with no human participation. It enables autonomous operation across the full production lifecycle without operating-scope restrictions.

Capability	Perception	Analysis	Decision	Execution	Optimization
L5	Full-domain full-status	Cognitive-level analysis	Scenario-wide autonomy	All-condition adaptation	Self-evolution

Note: L5 is the highest theoretical level. As of the release of this white paper, no commercial L5 system is available globally.

5 Classification Assessment and Evaluation

5.1 Assessment Process

Step 1 - Check the five capabilities: To what extent has the system achieved perception, analysis, decision-making, execution, and optimization?

Step 2 - Determine operating boundaries: What internal and external conditions define normal operation? Are there limitations?

Step 3 - Identify the decision owner: Is the dynamic cutting task led by humans or by the system?

Step 4 - Compare level definitions: Start from L0 and verify level by level whether the higher level meets all typical features of the lower levels.

Step 5 - Confirm the level: Based on the combined assessment, output the final classification level.

This assessment process is intended to provide a feasible method for classifying AI cutting machine intelligence. It represents Bodor Laser's technical understanding and is provided for industry reference and discussion.

6 Functional Capability Mapping

6.1 Six Functional Domains

Functional Domain	Code	Description
Drawing processing	F1	CAD import, CAM path generation, nesting and layout optimization.
Material transfer	F2	Loading, positioning, unloading, sorting, and stacking.
Process setup	F3	Cutting parameter matching, tool/nozzle finding, focus setting, adaptive parameters.
Cutting execution	F4	Motion control, energy output control, auxiliary gas control.
Quality control	F5	In-process inspection, defect recognition, quality judgment and tracing.
Collaboration management	F6	Multi-machine scheduling, MES/ERP integration, status management, predictive maintenance.

6.2 Functional Domain Coverage Matrix

Level	F1 Drawing	F2 Material	F3 Process	F4 Cutting	F5 Quality	F6 Collaboration
L0	Human	Human	Human	Human	Visual inspection	Human
L1	Automatic layout	Human	Automatic tool/nozzle finding	Constant speed/power	Offline inspection	Single-machine log
L2	AI nesting optimization	Semi-automatic	Parameter recommendation	Linked execution + monitoring	Offline inspection + assistance	Fault alarm
L3	Automatic + intelligent parsing	Automatic loading/unloading	Adaptive parameters	Automatic + real-time monitoring	AI detection + marking	Basic MES connection
L4	AI global nesting optimization	Fully automated flow	AI process knowledge base	Automatic + self-compensation	AI closed-loop correction	Deep MES integration + forecasting
L5	Self-learning evolution	Fully autonomous scheduling	Self-evolving parameters	All-condition adaptation	Self-diagnosis and repair	Supply chain self-coordination

6.3 Five-Capability Matrix by Level

Level	Perception	Analysis	Decision	Execution	Optimization	AI Cutting Machine?
L0	No	No	No	No	No	No
L1	Single-point	Basic	No	Assistive	No	No
L2	Multi-source	Basic	Recommendation	Linked	Conditional	Entry
L3	Real-time multi-status	Deep	Autonomous under conditions	Fully automatic	Conditional	Yes
L4	Full-domain multi-status	Deep + predictive	Fully autonomous in domain	Auto + self-compensation	Closed loop	Yes
L5	Full-domain full-status	Cognitive	Scenario-wide autonomy	All-condition adaptation	Self-evolution	Yes

7 Industry Application Outlook

7.1 Current Industry Level Distribution

Level	Current Industry Status	Representative Applications
L0-L1	Broadly adopted	Most basic CNC cutting equipment.
L2	Scaling up	Large-format laser cutters with process recommendation and fault diagnosis.
L3	Small-scale pilots	A few manufacturers achieve adaptive cutting and automatic re-cutting in defined scenarios.
L4	R&D; stage	Lights-out factory demonstration lines.
L5	Long-term planning	No commercial applications yet.

7.2 Significance for the Industry

For equipment manufacturers: The framework clarifies the R&D; roadmap, supports step-by-step breakthroughs from the L2 entry level, and guides the industry toward orderly improvement of core AI capabilities.

For end users: It helps users visually judge equipment AI capability and make more rational purchasing decisions based on reference levels.

For industry supervision: It provides technical language and evaluation-scale recommendations, supporting standardized expression of technical capability.

For the capital market: It provides measurable dimensions for technical evaluation and supports more reasonable valuation.

Appendix - References

SAE J3016_202104 - Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

GB/T 39745-2021 - CNC Laser Cutting Composite Machine

GB/T 40429-2021 - Taxonomy of Driving Automation for Vehicles

GB/T 12643-2013 - Industrial Robots and Robot Equipment - Vocabulary

This corporate white paper is intended to provide an AI cutting machine intelligence classification system as an open technical reference document. Based on this framework, Bodor Laser aims to work with the industry to build shared technical understanding and provide a reference blueprint for future national and industry standards for AI cutting machine intelligence classification, supporting high-quality development of intelligent equipment worldwide.