



Deploying Collaborative Robots in Small Metal Fabrication Workshops: A Review of Standards, Applications and Adoption Barriers

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Abstract

Collaborative robots are marketed to small manufacturers as machines that can be unboxed, taught by hand and set to work beside people without fencing. Metal fabrication workshops, with their short runs, skilled labour shortages and repetitive tending and welding tasks, are an obvious market. They are also a setting in which the workpiece and the process are often more dangerous than the robot. This narrative review examines what the published literature and the governing standards say about deploying collaborative robots in small fabrication shops. It first clarifies what collaborative operation means in ISO 10218 and ISO/TS 15066 and why safety is a property of the application and not of the arm. It then considers the three tasks most often proposed for fabrication, namely machine tending, welding and surface finishing, and the hazards each introduces. Programming methods for high-mix work and the organisational factors reported to help or hinder adoption in small firms are reviewed in turn. The literature is found to be rich on safety principles and interface design and thin on independent evidence from small workshops, where most accounts come from suppliers. The review ends by identifying the studies that would be needed to put deployment decisions on firmer ground.

Keywords: Collaborative robots, Metal fabrication, Small and medium-sized enterprises, ISO/TS 15066, Risk assessment, Human-robot collaboration

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1. Introduction

The word cobot was coined by Colgate *et al.* (1996) for a passive device that guided a load moved by a human operator. It now denotes something different: a lightweight powered arm with force sensing or current monitoring, rounded links and a teach pendant designed for people who are not robot programmers. Reviews of the industrial literature describe a steady widening of applications, from assembly in large automotive plants towards general manufacturing (Villani *et al.*, 2018; Matheson *et al.*, 2019).

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Small metal fabrication workshops are a natural target for this technology and a demanding one. A typical shop cuts, bends, welds and finishes sheet and section in batches that may run to a few dozen parts. Operators spend long periods loading press brakes and machine tools, welding repeated joints and grinding. Skilled welders are hard to recruit. A conventional robot cell, with its fencing, fixtures and specialist programming, rarely pays back on such batches. A robot that can be wheeled to a machine and taught in an afternoon appears to answer the problem.

Whether it does depends on matters the brochures pass over: what the safety standards actually permit, how the hazards of hot, sharp and heavy workpieces alter the picture, and what small firms need in order to absorb the technology. This review brings together the published work on those questions.

2. Scope and Approach

This is a narrative review of the published literature and of the standards and regulations that govern collaborative robot applications. It covers safety, task suitability, programming and organisational adoption, with attention to what is specific to metal fabrication and to small firms. The sources are standards documents, review articles and frequently cited primary studies in robotics and manufacturing research. No systematic search was undertaken and no claim of completeness is made. European regulation is used as the main legal reference; the international standards discussed apply more widely.

3. What Collaboration Means in the Standards

The governing documents are the two parts of ISO 10218, which address the robot (ISO, 2011a) and the robot system and its integration (ISO, 2011b), and the technical specification ISO/TS 15066, which supplements them for collaborative operation (ISO, 2016). These documents do not define a collaborative robot as a product category. They define collaborative operation, a state in which a purposely designed robot system and an operator work within a shared space, and they describe four ways of achieving it, summarised in Table 1.

Power and force limiting is the method most people have in mind when they speak of cobots. ISO/TS 15066 gives, in an informative annex, limits on force and pressure for transient and quasi-static contact with different regions of the body, derived from studies of pain onset (ISO, 2016). The scientific background lies in impact experiments such as those of Haddadin *et al.* (2009), who showed that injury from a robot depends on mass, velocity, the geometry of the contacting surface and whether the body part is clamped. Control strategies that scale robot speed with the measured separation between person and robot follow from the same reasoning (Zanchettin *et al.*, 2016).

Table 1: The four methods of collaborative operation described in ISO 10218 and ISO/TS 15066, and their relevance to fabrication tasks		
Method	Principle	Relevance to fabrication
Safety-rated monitored stop	Robot holds a monitored standstill while the operator is in the shared space	Loading and unloading fixtures between automatic cycles
Hand guiding	Operator moves the arm directly through a guiding device	Teaching weld paths; positioning heavy parts
Speed and separation monitoring	Sensors track the person; robot slows and stops to keep a protective distance	Tending and welding where contact must not occur
Power and force limiting	Contact is allowed; forces and pressures are kept below body-region limits	Light handling with blunt tools and parts only

Two points in the standards are regularly misunderstood. First, the requirements attach to the whole application: arm, end-effector, workpiece, fixtures and layout. An arm certified for power and force limiting does not make a cell safe when it is holding a sheared steel blank. Second, a risk assessment in the sense of ISO 12100 is obligatory for every installation (ISO, 2010), and safety functions implemented in the control system must reach the performance level required under ISO 13849-1 (ISO, 2015). In the

European Union the party that combines robot, tool and peripherals into a working cell takes on the manufacturer's obligations under the Machinery Directive ([European Parliament and Council, 2006](#)), which the Machinery Regulation will replace from January 2027 ([European Parliament and Council, 2023](#)). For a small shop that integrates its own cobot, that party is the shop.

4. Fabrication Tasks Proposed for Cobots

Three groups of task dominate the discussion of cobots in metalworking, and each raises the question of whether the method of collaboration matches the hazard.

4.1. Machine tending

Loading and unloading press brakes, lathes and machining centres is repetitive, and the operator is mostly waiting. A cobot at the machine door is the application most often shown. The robot's task is easy. The hazards come from elsewhere: sheet edges and burrs concentrate contact pressure far beyond anything the body-region limits contemplate, parts may be heavy enough that the payload dominates the moving mass, and the machine itself has crushing and ejection hazards with their own safeguards. Design guidance for collaborative workplaces accordingly treats the gripper and the part as central to the assessment ([Michalos et al., 2015](#); [Bi et al., 2021](#)).

4.2. Welding

Arc welding with a hand-guided cobot has spread quickly because teaching is intuitive for a welder: the torch is led along the joint and points are stored. The collaboration here is in the programming, not in the production cycle. During welding the process hazards govern. Arc radiation, spatter, hot metal and fume are present whatever kind of arm holds the torch, and the International Agency for Research on Cancer classifies welding fumes as carcinogenic to humans ([IARC, 2018](#)). Screens, extraction and separation are therefore required, and the cell in production behaves much like a conventional one with a lighter robot and an easier interface.

4.3. Grinding, deburring and finishing

Finishing work exposes operators to vibration, dust and awkward postures, and it is often named as a candidate for automation. The force control built into many collaborative arms suits contact tasks of this kind, and research on physical interaction has demonstrated shared control in which the person guides and the robot carries the load ([Cherubini et al., 2016](#)). A spinning abrasive tool is, however, a hazard that power and force limiting cannot contain, so such applications fall back on guarding or on separation monitoring.

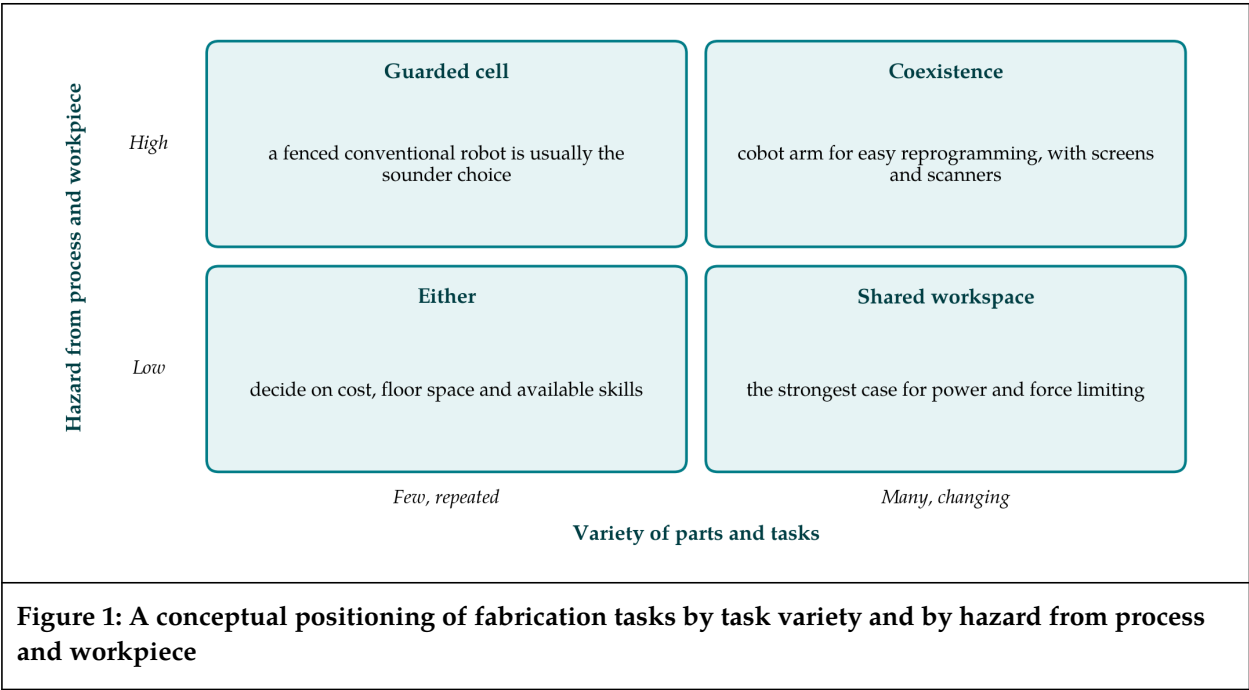
Figure 1 offers a simple way of placing a task. It sets the variety of parts and tasks against the hazard arising from process and workpiece. The diagram is a conceptual aid drawn from the reasoning in the standards and the reviews cited above; it does not summarise measured outcomes.

5. Programming for High-Mix Work

If batches are small, programming time decides whether automation is worthwhile. The literature describes several ways of shortening it. Hand guiding, or lead-through teaching, lets the operator show the path. Graphical and block-based pendant interfaces replace textual robot languages. Skill-based programming packages recurring operations, such as pick, place or follow a seam, into parameterised units that a shop-floor worker can sequence ([Pedersen et al., 2016](#)). [El Zaatari et al. \(2019\)](#) survey these approaches and observe that ease of teaching a single motion does not by itself give robust programs: handling of part variation, error recovery and communication with the tended machine still call for engineering knowledge.

Intuitive interfaces are one of the three themes around which [Villani et al. \(2018\)](#) organise the field, alongside safety and applications, and the wider survey literature records a decade of work on gesture, speech and augmented-reality interfaces ([Hentout et al., 2019](#)). Much of that research has been conducted in laboratories or large plants. Its fit to a workshop where the same person welds, sets machines and now

programs a robot has received less attention.



6. Adoption in Small Firms

Studies of adoption point to factors that have little to do with robotics. Charalambous et al. (2015) identify organisational human factors for introducing human-robot collaboration, among them communication of the change to the workforce, operator participation in implementation, training and visible support from senior management. Kildal et al. (2018) explore the concerns and expectations of potential users, among which safety and ease of use feature prominently. Simões et al. (2020) examine managers' intention to adopt cobots and find it shaped by organisational and environmental considerations as well as technical ones.

For a small fabrication shop these factors take a particular form. There is usually no automation engineer, so the risk assessment, the integration with the machine and the upkeep of programs fall to the owner or a senior operator. Suppliers and integrators fill the gap, at a cost that alters the investment case and with a dependency that the firm should recognise at the outset. Trust is a further matter. An operator who has been told the robot is safe to touch may extend that belief to situations, such as a change of gripper, in which it no longer holds. Human factors of this kind are treated as part of the safety problem, alongside the technical safeguards, in surveys of collaborative robotics (Vicentini, 2021).

Productivity expectations also need care. Speeds permitted under power and force limiting are low compared with those of a fenced robot, because allowable contact energy falls with the mass in motion. A cobot is rarely faster than a person at the task it takes over. The economic argument usually made rests on releasing skilled labour for other work, on consistency and on unattended running during breaks and after hours, and those benefits depend on how reliably the cell runs without intervention.

7. Gaps in the Evidence

The published record is uneven. Safety principles, contact biomechanics and interface concepts are well covered. Independent, peer-reviewed accounts of cobots in small fabrication workshops are scarce, and much of what circulates consists of supplier case descriptions that report successes and omit the cells that were quietly retired. Three kinds of study would help. Longitudinal field studies in small shops should follow installations over years and record utilisation, reprogramming effort, stoppages and safety-related events. Engineering studies should measure contact forces and pressures with realistic fabrication end-effectors and parts, since the published limits presuppose blunt contact. And research on competence

should establish what training a shop-floor integrator needs to carry out a defensible risk assessment.

Standards are also moving. Revised editions of ISO 10218 were published in 2025 and bring guidance on collaborative applications that formerly sat in the technical specification into the main standard, and the European Machinery Regulation changes the legal frame. Guidance written for small firms on the earlier documents will need to be revisited.

8. Conclusion

The literature supports a qualified view of collaborative robots in small metal fabrication. The technology lowers the cost of entry to automation, chiefly through easier programming and smaller cells, and it suits the short runs on which such workshops live. It does not remove the need for safeguarding where the workpiece is sharp or hot or the process emits radiation and fume, which in fabrication is most of the time. Safety belongs to the application, responsibility for it rests with whoever integrates the cell, and success turns as much on organisation and competence as on the arm. Better independent evidence from small workshops is the most pressing need.

Conflict of interest

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