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Challenges for Manufacturing SMEs in the Introduction of Collaborative Robots

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Abstract. Collaborative robots, cobots can be an alternative to traditional industrial robots, but for small and medium-sized enterprises, SMEs, the adoption still is in an early stage. This study, a combination of literature study and interviews with staff at companies and reserachers, aims to identify the challenges for manufacturing SMEs when introducing cobots in the business so that future work in companies can be based on these finding facilitating a smooth implementation. The mainchallenges identified are related to safety, performance, strategy, involvement, and training. Safety aspects are crucial since human operators work closely with collaborative robots and risk serious injuries even though the managers and operators in the case study do not seem to worry since they perceive the current cobots as relatively slow and safe. Other high-prioritised challenges are related to performance and strategy, e.g., how to achieve cost-effectiveness with small production volumes and get the robotic investment to pay off in the long turn, but also to choose a proper cobot solution and a reliable supplier, find suitable work tasks and obtain quality if the cobot fails to recognize a defective product or skewed inputs on the production line. Employee involvement is another success factor since early involvement of the operators leads to better acceptance and understanding of the new technology and the changed work situation. There is a need for skilled, educated workers as well, although the case study shows that the SMEs highlight the importance of choosing a robot system that is easy to learn and easy to use for everyone. This paper will discuss challenges when introducing cobots in manufacturing SMEs.

Keywords. Human-robot collaboration; HRC; collaborative robots; cobots; SME

1. Introduction

Collaborative robots are a relatively new category of robots introduced to the market during the last decade [1], under the term “cobot”[2]. In this paper, the word cobot will be used for collaborative robots. Cobots are defined as “a class of robots that perform tasks in collaboration with workers in industrial sectors” [3]. They are seen as an alternative to traditional industrial robots since they are more flexible, less space-consuming, and can share the workspace with human operators. While traditional robots are strictly separated from human operators by physical obstacles as fences or cages, cobots are placed in the same workspace as humans. Traditional robots need a large physical workplace, while cobots require less space and could easier be allocated in other parts of plants [4]. Cobots are considered to be easy to install, program and reprogram, and can be adapted to different tasks, which is a crucial factor in today's production systems. Important are also the paradigm shift from mass production to mass

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customization and a need to handle more variation in production, with shorter life cycles and smaller batch sizes [4-6]. On the other hand, depending on the task, cobots can require several safety devices, e.g., vision systems, which can recognize human body gestures and facial expressions [6]. They can also be equipped with, e.g., force limits, force and torque sensors, anti-collision systems, and voice command recognition [4].

Manufacturing SMEs, namely companies with 9-249 employees [7], are increasingly using cobot systems, while they offer affordable compact solutions that are easy to use [1]. Many SMEs deal with smaller lot sizes, limited space, and a lack of skilled expertise for the installation and programming of traditional industrial robots [8, 9]. Although cobots are relatively new within the SME manufacturing industry, implementation challenges are not much explored yet.

This study aims to identify the challenges for SMEs when introducing cobots in the manufacturing industry. Since human-robot collaboration, HRC, still is a rather new field for SMEs, this qualitative explorative study has the purpose to gather rich insight about the field and the obstacles SMEs can face while implementing cobots in the business.

HRC, is defined as a "state in which a purposely designed robot system and an operator work within a collaborative workspace" [10]. Collaborative robotics is a core technology of Industry 4.0 to enhance work conditions and efficiency [11]. The main idea of HRC is to combine the abilities of a human and a robot. On the one hand, there are human cognitive skills and sensorimotor abilities: a human operator can be flexible and judge, react and plan, and improvise decision-making. On the other hand, there is the robot, which never gets tired and can work fast and repetitively, with dangerous tasks without losing focus or precision [1, 5, 6, 9, 12-22]. To some extent, humans and robots are sharing the workplace, even if the level of cooperation can differ. Four possible levels of interaction are coexistence, synchronization, cooperation, and collaboration [1, 6, 14, 23-25].

- Coexistence: the operator and the cobot are close, but they do not share the workplace.
- Synchronization: The operator and the cobot do share the workplace, but not at the same time.
- Cooperation: The operator and the cobot are in direct contact but work on different tasks.
- Collaboration: The operator and the cobot work together and have direct contact.

Several automotive manufacturers have been introducing cobots in assembly production lines recently [21]. According to the International Federation of Robotics, IFR, the market for cobots is in its infancy, the end-users and system integrators are still exploring what works well and what does not work in the design and implementation of cobots, when it comes to, for example, sensors, grippers, and more intuitive programming interfaces [3]. The cobots are flexible and can quickly adapt to different tasks, which is an essential factor in today's production systems, with a paradigm shift from mass production to mass customization and a need to handle more variation in production, with shorter life cycles and smaller batch sizes.

SMEs are the backbone of most economies [26]. In Sweden, 99,9% of the companies are SMEs [27], and in the European Union, SMEs represent 99% of all business [7]. Many SMEs require reduced lead times and flexible multi-purposed assembly systems, and the need for flexibility in production is one factor that affects the choice to invest in cobot solutions. Though the adaptation is still in an early stage [28] and the barriers for

adopting Industry 4.0 approaches and technologies are high with technical challenges regarding competence in, for example, mechanical, electronic, and software engineering in automation technology, and also challenges on an administrational level when it comes to the development of new business models and employee training [26]. Other factors pointed out as barriers for SMEs in the Industry 4.0 implementation are lack of knowledge, understanding of development and improvement of technology, and awareness of the technology in production [29].

The disposition of the paper is as follows: First, cobots in the context of SMEs are presented. Next, the research method is presented, as well as the results based on the top categories found in the analysis. Finally, the results are discussed, and conclusions are drawn.

2. Research method

The study has a qualitative research approach. A systematic literature review has been conducted and an exploratory case study with five manufacturing SMEs and three researchers within the field.

2.1. Literature review

The literature review was conducted by search in Academic Search Elite, Scopus, Web of Science, and Google Scholar. The methodical approach was inspired by Oates [30], where the keywords and search phrases are sorted from a phrase that defines the subject. The following search was done in references from the found articles as well. Four concepts were chosen from the phrase *"Challenges for SMEs when implementing human robot collaboration"*: challenges, SMEs, human robot, and collaboration. Then, alternative terms for each concept were found by looking for synonyms for the concepts and reading keywords in different articles in the area and combined in different search strings.

Based on the search strings, 43 articles were found, where the majority were published between the years 2019 and 2020. The author's primary affiliations are engineering, even if there are authors from the areas of e.g. computer science, business and economics, and management sciences. The result was analyzed in a three-step process, inspired by [31], who suggests an approach where the core maps and outlines are organized related to the themes, a historical log is created out of scanning processes, maps, core ideas, keywords, and notes are arranged to build up evidence categories.

2.2. Case study

The empirical material was gathered through semi-structured in-depth interviews with SMEs and researchers. Four interview guides were made: one for companies who have implemented a collaborative robot, and one for companies who are about to implement it, one for operators and one for researchers. The questions were sorted under focus areas, as for example driving force, safety, education and future solutions.

The company interviews were conducted with managers, engineers and operators from five manufacturing SMEs located in western Sweden in different sectors: furniture production, sheet metal assembly and manufacturing, food processing, and plastic extrusion. They have implemented, or are about to implement, one or two robots each,

working with welding, lifting, packaging, pick and place and polishing. Totally, eight persons were interviewed. The level of collaboration in the SMEs is mainly coexistence, where the operator and the robot work close together but not in the same workplace.

The researcher interviews were conducted with researchers within the the area of manufacturing and production engineering. Totally three researchers from Sweden, Hungary, and Germany were interviewed.

2.3. Data analysis

In the analysis process, themes and categories were identified through an inductive approach, which gathers information through open-ended questions. The data is analyzed by looking for broad patterns to form themes or categories from which generalizations or theories are created [32].

The categories were refined, and themes and interconnections between them were searched for. The findings from the SME interviews were triangulated with the findings from the researcher interviews and the literature review.

3. Identified empirical challenges related to literature review

The challenges differ a bit between the literature, the companies, and the researchers, as shown in Figure 1. While the literature highlights issues about safety, the companies talk more about performance and the researchers about smart technology. Performance is not one of the top three categories in the literature review, which could have been affected by the choice of search phrases. Same with the category "smart technology", since that was not in the literature review scope or company interviews. The fact that the researcher interviews highlight issues about smart enabling technologies can be explained by a selection bias since they all are active in that research area. Also, the researcher interviews had a bigger focus on future solutions.

Literature review	Company interviews	Researcher interviews
1. Safety	1. Performance	1. Smart technology
2. Strategy	2. Involvement	2. Strategy
3. Training	3. Safety	3. Safety
	4. Strategy	

Figure 1 Challenges for manufacturing SMEs, according to the literature review, company interviews, and researcher interviews. Since categories 2-4 in the company interviews are similar in size, this section has four categories.

After triangulating the result from the literature review, the company interviews, and the researcher interviews, five main categories have been identified as the biggest challenges for SMEs in the introduction of collaborative robots: safety, performance, strategy, involvement & training, and smart technology. See Figure 2 for order of priority.

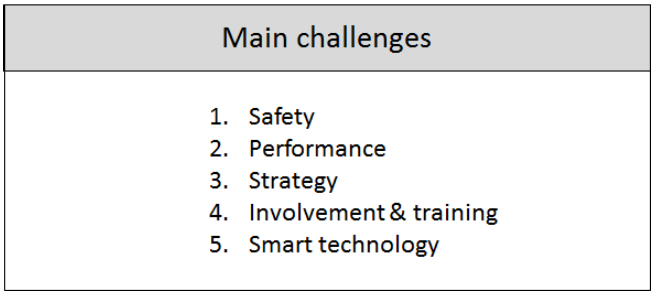

Figure 2 Overall challenges in order of priority for manufacturing SMEs when introducing cobots.

Each category will be described below, followed by a discussion about similarities and differences in the results. In this section, the categories Involvement and Training have been merged. Where the managers are mentioned in the text, that includes the engineer since that is only one person who could easily be identified if mentioned separately.

3.1. Safety

Safety aspects are crucial since human operators work closely with collaborative robots and risk serious injuries. Working close to robots without barriers may introduce new risks for humans related to exposure, contacts, and collisions [9]. One of the interviewed researchers in this study states that there is an extra level of challenges here, since the aim is to combine the best things of the two worlds of humans and robots, and at the same time, everything must be done to keep the human safe. *"If you combine those two worlds, the robot becomes very slow. It is weak while the human is there",* the researcher says. Proper safety assessments are essential as well, according to the case study and the literature review. One of the researchers means that SMEs overestimate HRC and underestimate the safety risk.

The international ISO standards 10218-1 [10] and 10218-2 [33] are the primary safety standards for applications of industrial robot systems and cover safety prescriptions. In addition to this, the technical specification ISO TS 15066 [34] provides guidelines for the design and implementation of a collaborative workspace and guidelines for risk assessment. During the company interviews and the researcher interviews, a concern about the lack of proper safety regulations was raised since the available ISO/TS 15066 is just an addition to the robot directive. A need for more specified safety standards for the collaboration between humans and robots was also raised in interviews and literature reviews. For example, [22] highlights the need for new ways of determining safety in collaborative environments, connected to the operator's skill level or the specific activities the robot and the human are performing. Also, [14] state that safety standards must be rethought because of the differences between HRC assembly and conventional industrial manipulation and that minimum distance and hazard zones must be redefined as well. The installations of cobots require risk assessments, including hazard identification, risk evaluation, and risk reduction [35], and risk assessments should be included in the early stages of product layout development [12, 35].

While the researchers raise concerns about the lack of safety standards and the risk of SME managers going to prison while risk assessments are not correctly done, the companies in the case study highly rely on the suppliers and their knowledge about safety and CE marking. However, one of the companies has had the experience of two robot suppliers with diametrically different views of the safety aspects in a specific workstation. One manager at another company experiences the regulations as "fuzzy", and the researchers raise concerns about the lack of proper safety regulations.

The company interviews, the literature review, and the researcher interviews highlight issues about trust, but from different perspectives. While the focus in the literature is on human trust in cobots, and fear of injuries, the operators and managers in the case study rather talk about trust in the automation process and fear of losing jobs or unwillingness to change work methods. The researchers raise the question that the operators have to be aware of the cobot all the time, and one of them states that the trust must be mutual, while the robot has to trust the operator as well. The literature study shows that the operator's trust in the cobot is one key to a successful collaboration [9, 12, 19, 36]. If the operator does not trust the cobot, the performance can drop, and the robot system could be underutilized. In [36], the authors state that human safety and trust in automation are the main challenges in HRC. Any form of collision could affect the human operator's trust in the cobot, and strategies for avoiding collision are critical to building the trust. According to [9], trust is the most important human factor when introducing cobots in enterprises during the decision and operation phase. Although, the operators in the case study do not see any safety problems since they either consider the cobot to be slow or are working at a distance from it. None of them have experienced any incidents with the cobots so far, and the interviews do not indicate any fear of injuries among the operators. *"I am very safe with it. It is not that big, it does not go fast and cannot surprise you",* one of them states. In some case study companies, the operators have had the opportunity to test what happens if they touch the cobot while it is running, feeling how it senses before it slows down and stops. Most managers and operators also express a high level of trust in the cobot supplier and their knowledge about CE marking, which they do not think would be possible to have in their own organization. *"We do not have that knowledge, but expect them to have it",* one of the managers says.

3.2. Performance

Other challenges are related to performance, such as speed, time, quality, and worker satisfaction. Most of the respondents from the company interviews mention performance as the most significant benefit of the cobot, while it can be fast, time-saving, and always gives the same result. Although issues regarding performance are the main challenge according to the companies in the study, they have to find a way to make a profit with the collaborative robot due to small production volumes and speed since the processing time affects by reduced work pace due to safety considerations.

Another performance-related issue is the quality of the work. Both operators and managers talk about the high quality related to the cobot's precision, which makes it easier to maintain high quality, even though there are some quality checks that the cobots cannot do. In one company, the packing cobot cannot see defective products; therefore, the products must be manually checked, which makes the operators stressed since they have a hard time keeping up with it without slowing down the process. *"It does not matter how good the cobot is if it just picks garbage",* one manager states. During the case study, one of the companies decided to send their new cobot back to the supplier

while working too slow and did not live up to their expectations. The operators had to do the same task in parallel to be able to finish in time. Another respondent states that the cobot has limited speed relative to the operator's proximity in their workplace, which is another bottleneck. If the staff often is too close, it leads to many situations where the cobot slows down and stops.

3.3. Strategy

The companies in the case study are talking a lot about challenges related to strategic issues, e.g., cost-effectiveness with small production volumes and get the robotic investment to pay off in the long turn, but also to choose a proper cobot solution and a reliable supplier, find suitable work tasks and obtain quality if the cobot fails to recognize a defective product or skewed inputs on the production line. They are struggling with the ability to make a profit in automation despite small volumes. One of the managers thinks that the key to success is to begin with an easy task and see the cobot solution as a long-term investment.

Another important thing, according to both the case study and the literature study, is to find a flexible cobot solution that suits each company's needs. In [37], the authors state that cobot solutions require much work, while there are no strict standards, procedures, and steps for implementing in an enterprise. According to [24], this makes it hard for especially SMEs to understand when the cobot solution should be implemented and in which area in the manufacturing system. They mean that many companies lack the expertise and need a clear Robot & Automation strategy for a successful cobot implementation and tend to choose too complex automation tasks and too high levels of interaction. Also, [22] states that it is hard to motivate investment in a robot cell if the volume is too small. They conclude that cobots have the biggest potential in the middle product volume area. It is also important to decide what assembly tasks should be performed by the human and what should be performed by the cobot. According to [38], the biggest challenge is identifying a suitable workstation, according to robot manufacturers, system integrators, and HRC users.

3.4. Involvement and training

Other challenges are related to involvement and training, including the need for education and expertise and involving the employees in the process. The literature review points out the need for skilled, educated workers to introduce new technology in manufacturing systems in general [39] and in the cobot introduction [24, 40, 41]. Training and education have been identified as essential factors for introducing cobots in SMEs, as well on a management level, regarding technology awareness and benefits, as on an employee level, regarding technical training and understanding the functionalities [40]. According to [8], the lack of expertise is the main risk of Industry 4.0 for SMEs. The search for necessary skills is crucial in implementing an Industry 4.0 project since the technical competence must support the technologies. This can be met by engaging external experts, training the employees to limit the lack of expert support functions, recruiting new skills to the company, or simplifying the tools [8]. In [26], the authors state that even if different companies have the same infrastructure or machinery, the competence, e.g., research projects, industrial projects, and experiences, indicates how the capabilities can be pushed to the limits in terms of using the skills. Although, the case study shows that the SMEs instead highlight the importance of choosing a cobot

system that is easy to learn and easy to use for everyone, without long training or education. Overall, the cobot systems are considered to be easy to learn by both operators and managers in the company interviews. If there is an error, they rely on support from the cobot supplier.

Employee involvement is another critical issue for the companies in the case study, while it leads to better acceptance and understanding of the new technology and the changed work situation. According to the literature review, involving the operators from the beginning is a way of better accepting and understanding the new technology and changing work situations [9, 13, 17, 42]. According to [42], the full potential of HRC can be exploited only if the humans involved accept the technical system. In [9], the authors state that it is essential to be transparent about changes and inform the employees, that often associate robot systems with a fear of being replaced. They mean that high involvement in the introduction process creates a feeling of participation and identification with the project and can encourage the employees to support the initiative and that there is a thin line between mistrusting the cobot or seeing it as a trustworthy supporting device. This is confirmed by the case study, where a key to a successful cobot introduction seems to be staff involvement already in the planning phase. In one of the companies, some of the employees were skeptical from the beginning towards the investment. In another, some operators were worried about not being able to handle the technology. Therefore the company required from the beginning that the robot system should be straightforward to use. *"It cannot be troublesome. Then the staff will not use it"*, one of the managers said. The case study also showed that transparency about the process towards the employees is essential.

In several companies in the case study, the employees were involved in initial discussions about which work elements the cobot should perform. The operators attended study visits to where the cobot was manufactured and to workplaces with similar cobots in production. One of the operators expresses the thought that this led to higher motivation and a shorter implementation phase since it probably had taken longer to start if the employees had not been involved from the start. *"It becomes more fun if one feels involved from the beginning",* one of the operators says. In the researcher interviews, employee involvement is not mentioned at all. This could be explained by their research being more on enabling technologies and safety and not on organizational issues and human factors.

In choosing proper work tasks for collaborative robots, the literature shows that there are many decisions to make, and many SMEs lack the knowledge and tend to choose too complex tasks. The companies recommend easy tasks to start with; otherwise, the employees will not be motivated to work with the cobots.

3.5. Smart technology

The interviewed researchers highlight the need for more intelligent solutions equipped with enabling technologies. The SME managers call for flexible, removable solutions with sensors and vision systems for quality control, handling surprises, and offering information to the human operator. *"It should be like a nurse helping the surgeon",* one of them says. One researcher calls for better vision systems and states that the available safety vision systems are not smart enough to ensure safety for the operators. Another researcher highlights the challenges of planning operations and states that everything should be put into a digital twin, which is a virtual representation of the physical workplace.

While the researchers call for intelligent vision systems, monitoring modules, and AI solutions to handle a higher performance, there seem to be less interest in smart technology amongst some of the companies in the case study, even if some of them also state that they need more intelligent additional systems to discover defective products, for example. The literature suggests reconfigurable cobots, which could be moved between workstations, which some of the companies call for as well. According to the companies in the case study, the kind of solutions SMEs need in the future is flexible cobots, which can be moved around to different workstations. There is also a need for smarter enabling technologies, where the cobot is integrated into a machine learning environment, equipped with sensors and vision systems, connected to a risk assessment system, and a digital twin.

4. Conclusion

This study has identified five main challenges related to the introduction of cobots in manufacturing SMEs. Their related prioritization are:

1. Safety
2. Performance
3. Strategy
4. Involvement & training
5. Smart technology

The obstacles are related to achieving cost-effectiveness with low production volumes and lack of long-term strategies and distributing the tasks between humans and cobots. There is a need to involve the employees early in the process; also, in choosing suitable work tasks for the cobot, the management must be involved as well. The lack of knowledge about the cobot market can also be an obstacle regarding finding the right cobot supplier and a cobot solution that will suit the demands of that specific company. The challenges when the cobot is in place are related to proper risk assessments, finding the correct settings for the work moment and task, finding the right products, and obtaining quality, for example, when the cobot cannot distinguish defective products. The future challenges in the area of HRC, according to the researchers, are related to learning and how to create a dynamic, learning environment: *"The cobot should not be a burden for the operator. It should be like a nurse that helps the surgeon",* one of them states.

This paper is based on an individual study. Future work would embrase more involved companies and respondents. A long-term study could also follow up the cobot investments to investigate if collaborative robots are profitable in the long term for SMEs and if they live up to the desired level of effectivity, speed, and worker satisfaction.

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