Communication and co-operation for flexible and robust production systems

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Abstract
Manufacturing companies must handle change and dynamic conditions to stay competitive. For achievement of a flexible and robust production system, the full potential of technical as well as human resources need to be properly utilized. By developing robust production systems, able to compensate for changes and variation, the production efficiency will increase. Similarly, if the variety of competences and experiences of the employees’ (e.g. operators, maintainers, engineers and designers) are acknowledged and properly utilized, the overall performance will also be improved. This paper presents results from case studies at two manufacturing companies, focusing on information exchange and communication during design and mainly operation of production systems with the purpose of achieving robust production. Management of information and the utilization of different co-operation forms are discussed as tools for communication among personnel from different disciplines. By facilitating a problem-solving environment within production, the possibility of handling dynamic conditions and improvements will increase.

1 Introduction
Production disturbances (e.g. break downs, idling or minor stoppages) are unfortunately quite common in the manufacturing industry today. Disturbances arise due to both externally and
internally generated uncertainty and variation according to Almgren (1999). In organization theory, one core issue has been the kind of uncertainty that organizations have to deal with, and how these uncertainties are handled by the organization (Grote, 2004). Two basic approaches for the management of uncertainties are presented by Grote (2004): Either minimizing the uncertainties, or coping with the uncertainties. A balance between the two mentioned approaches through loose coupling is argued by Grote (2004). In this paper, activities aiming to prevent and eliminate disturbances are synonymous to the approach of minimizing uncertainties, while handling or coping with disturbances and changes are similar to coping with uncertainties. In accordance to Almgren (1999) we find uncertainty as “the relation between the amount of information needed and possessed”. Information about uncertainties and/or production disturbances is important in order to determine the proper activities aiming to eliminate, prevent or cope with these events. Complex problems can not be solved in isolation by e.g. maintenance or industrial engineers. Instead, these challenging problems could be prevented or handled by enhanced communication, co-operation, and learning within cross disciplinary activity groups, i.e. teams consisting of individuals from different disciplines with complementing competences and experiences.

Robustness of production systems may be considered at different organizational levels in an industrial company. At the strategic level, the success of a company is dependent on how the company handles its own ability and capacity and the preconditions of the surrounding world (Frankelius and Rosén, 1993), or in other words: “All companies change in time, whether the change is done by conscious control based on good advance planning or due to a forced adaptation to a changeable world” (Frankelius and Rosen, 1993). At the operative level, the robustness of the production system is dependent on both technical and human flexibility,
since the ability to compensate for variation and dynamic conditions will be of major importance for the achievement of high manufacturing efficiency within the system.

This paper illustrates the need of relevant communication and co-operation forms between actors from different disciplines in activities aiming towards robust production systems (minimizing or coping with uncertainties and changes). Also the need of pragmatic information will be discussed. The emphasis is on the operative production level, although some of the important strategic aspects will also be mentioned.

2 Frame of reference

2.1 Robust production systems

The robustness of a production system is indicated by the level of disturbances during different phases of the system life cycle. Production systems with the ability to operate in spite of frequent changes and disturbances may be considered “robust” (Harlin, 2000). The robustness of a production system both includes - and is dependent on the flexibility of both technical and human resources. Robust technology may compensate for changes in terms of external and internal variation. Human robustness on the other hand is synonymous to the human ability to cope with changes and to learn in real time – as long as they can freely perceive and integrate environmental information (Alm, 1996). Different types of changes that for example operators are dealing with require what could be called ‘pragmatic information’, i.e. information which may generate appropriate measures (Alm and Fjällström, 2003).
Operators tend to work as human buffers in complex production systems. This is due to the fact that they have to compensate for the lack of technical robustness of the system which often results in production disturbances (Bainbridge, 1983; Döös, 1997; Harlin, 2000). As long as operators regard disturbances as a normal state and a part of their daily work, actions will be taken to solve the problem on a daily basis. However, there is still a risk that the long term solutions aiming to eliminate or prevent the disturbances from occurring at all will not be prioritized with such an approach. Disturbances in production is not a concern for operators only, but also an important issue for maintainers, engineers, designers, managers and suppliers to deal with. Therefore, communication and co-operation between these actors is vital for the robustness of existing as well as new production systems. Hence, for achievement of a flexible and robust production system, the full potential of technical as well as human resources need to be properly utilized. It requires management of information and the utilization of different co-operation forms for successful communication between the actors.

2.2 Pragmatic information, communication and co-operation

Activities aiming towards robust production systems are supported by pragmatic information, communication and co-operation between actors from different disciplines. Pragmatic information is defined as information that generates ‘information potential’ or ‘potential for action’ (Weizsäcker, 1974; Bateson, 1972). What is seen as pragmatic information is dependent on the pre-knowledge of each individual (Alm and Fjällström, 2003). A highly skilled and experienced operator may hear that something is not right by a very subtile change of the sound of a machine in the processing mode, and instantly stop the machine to avoid a full break down. For an inexperienced operator or a designer with no or small experience from this specific machine, this event may pass without any special notice. The more pre-knowledge an individual have, the more environmental information will be regarded as
pragmatic information and in turn expand the frame of reference by generating new knowledge. Similarly, when a group of people with different frame of references work together, they will come up with better problem solutions than if each individual worked on the problem in isolation.

In the context of production disturbance handling, information of the disturbances is needed. This information must be communicated to engineers and designers for preventative measures. By communication we here refer to the transmitting of information by medium or information carriers such as speeches, texts, pictures, figures or models, see also Merriam-Webster (2002). However, information about disturbances is not only communicated in order to make engineers and operators aware of the problem. It also has the purpose of resulting in a reaction in terms of a problem solution. In this example, the reaction is triggered by the interaction between the operator’s and the engineer’s view of the problem. Integration occurs when interaction is a joint effort (Persson, 2002). Integration of activities, work procedures, methods, tools and software systems are preconditions that restrict or enlarge the extent of cooperation and collaboration between actors from different disciplines. Synergy effects are achieved in collaborative integrated work and result in mutual benefits for all parties. Such synergy effects are essential to achieve robust production systems.

Communication and co-operation, triggered by interaction between actors with different individual’s perspectives and pre-knowledge, will also increase the understanding of sometimes conflicting perspectives and goals. This type of interaction implies learning between the interacting people, e.g. when the team is involved in solving the upcoming problems of production disturbances. Such a ‘team-learning’ is triggered by dialog and by learning together in a group. If the team develops, the organization will in turn be developed
(Senge, 1995). Organizations encouraging and utilizing communication and co-operation between actors both within and between organizations, will certainly have better preconditions to prevent disturbances and cope with changes in production. Examples of preconditions for communication and co-operation that could be mentioned are: meeting areas for both formal and informal meetings and an open climate or culture, which allow a creative and problem-solving environment. Such an environment should be based on group dynamics and characterized by reflection and curiosity. Communication is also supported by a terminology that is shared by the actors as it facilitates both interpretation and understanding. In addition, according to Rouse et al. (1992) communication performance is dependent on the team members’ ability to form appropriate expectations and explanations of the communication.

3 Research design for the empirical studies

The empirical results presented derive from case studies at two Swedish manufacturing companies, here labelled Case A and Case B. Case A was performed during 2001-2002 at a production plant for parts manufacturing, where a selected production line was studied. During 2002-2003 a second case study, Case B, was performed at a casting plant within another manufacturing company.

Different techniques were chosen for data collection within each case study, e.g. observations at (improvement) meetings, questionnaires, semi-structured interviews, studies of documentation, and analysis of a software system for automatic collection and presentation of production disturbance data. Preliminary research results were discussed at industrial workshops at each
participating company for validation of the specific results and for identification of problems and possible improvements related to production disturbance handling at the companies.

4 Case study results

4.1 Case A – a parts manufacturing system

Case A dealt with a highly automated production line for parts manufacturing comprising gantry cranes and built-in machine processes. The main flow consisted of six working stations with nine multi-processing machines and specified machines for washing, drying, controlling, and inspection. Operator teams with 6-8 individuals per team worked in three shifts at the shop floor level. The teams were responsible for the main flow section and typical work tasks performed within the operator teams were programming, maintenance, tool changes, and inspection. A part of the work also implied problem solving in terms of handling disturbances and uncertainties. The maintenance function, specialised within mechanical and electrical areas, was under reorganization during the time of study, and outsourcing of the function was discussed. However, maintenance was still located in the same building not far from the studied production line both before and after the reorganization, implying physical nearness to the production area.

The company conducted a TPM program, modified to suit the specific organization with the goal of reducing its sensibility towards disturbances but also to increase capacity by improved utilization of existing resources. The goal was to achieve standardized working procedures were local work teams were responsible for systematically increasing the process and
equipment efficiency. The program included changes in organization, methods, procedures, and principles (Bellgran, et al., 2002).

At shift changes, information about production disturbances and other events that could affect the technical robustness of the production system were communicated both by informal discussions with other operators as well as in written format in so called ‘shift reports’. Furthermore, a software system used for machine stops and disturbance registration, and a TPM-notice board were other channels for the capture of contextual and situational knowledge. By being updated on previous changes and occurring production disturbances, the operators could be better prepared for the system’s behaviour if similar or new disturbances would appear. Consequently, the human robustness of the production system was secured by both formal information about disturbances and other production events and informal communication with colleagues and others.

Operational improvement work at the production line was handled by so called ‘local work teams’. Each work team involved mainly operators, but also maintainers and production engineers connected to the studied production line. There were altogether three improvement groups, since each work team basically consisted of each shift team. Improvement meetings were carried out once a week. A tool used for collection of production disturbances between the time of the improvement meetings was disturbance registration of the bottle neck machine (both automatically by a software system and manually by added categorizes and explanations of the event or disturbance). Any operator or other personnel connected to the production line that had an improvement proposal could easily fill in a form and place it at the TPM-notice board at the centre of the production line. These disturbance data and improvement proposals were gathered and discussed during these so called ‘improvement meetings’, which mainly
focused on maintenance and improvement activities, including bottle-neck analysis and problem-solving. The improvement meetings were conducted by each operation leader of the shift team.

Communication and co-operation during more formal conditions, were supported by the new organization. In order to provide the strategic work with improvement ideas as well as utilizing the improvement proposals from the local work teams, the company had different formal forums for discussions. This system aimed at reducing the real time decisions in the organization. Each operation leader was, apart from the local work team (figure 1, level 4), also part of a local management group (figure 1, level 3), involving also production engineers, process planners, and conducted by the production manager. Since both operators and maintainers in general were involved with the daily production, the local management group functioned as a support for improvement measures on a more strategic and long term basis. The production managers were part of another forum as well, implying support and planning on the plant level (figure 1, level 2). Yet another discussion forum existed, which was conducted by the manufacturing plant manager (figure 1, level 1).
Even if the actors presented in figure 1 were doing progress in their improvement work at the studied production line, potential areas for improvements could still be identified. The possibilities of working proactively with production disturbances during larger changes and development work were here affected by factors related to shortages within:

- personnel
- knowledge
- time
- information

Also the robustness of human resources was insufficient, due to a high staff turnover of operators as well as of production planners. The high production pressure in combination with the undermanned staff in production led to an overall stressful work situation for operators, as well as less time for preventative maintenance and improvement activities. The staff turnover also resulted in competence losses and made the long term work more problematic. Another hindrance factor for an optimal disturbance minimizing and coping situation was that the production was prioritised before maintenance activities due to the need to focus on the production output. This implied that production was not stopped for activities such as preventative maintenance, and work methods were based on a short term rather than on a long term basis. Finally, information shortage or deficiency in the communication was mentioned by maintainers who spent much time working with production problems caused by changes in
raw material. Time could have been saved by better communication about the kind of changes that directly or indirectly affected the work of the operators and maintainers.

4.2 Case B – a casting plant

In case B, a casting plant was studied. The main flow of the studied production cell within the casting plant was automated and consisted of six main processes; die casting, trimming, recasting, balancing, magnetisation, labelling, and final inspection. Since the studied production cell was an important internal supplier of flywheels, the production was a potential bottle neck for the majority of the assembly plants in the company. There were five operators, in total that worked five shifts at the studied production cell, i.e. one operator per shift. Each operator was therefore responsible for the whole flow section, and typical work tasks were programming, maintenance, tool changes, and quality inspection. Part of the work also implied supplying machines with material and handling disturbances. Maintainers, engineers and management connected to the production cell worked day shift, which meant that the production output was very much dependent on the competence level of the operators and problem solving ability, especially during night shifts and weekends. Communication at shift change, with the operator from the previous shift, was fundamental in order to get information about previous production disturbances and other events. This information could affect both the technical as well as the human robustness of the production system.

At the time of the study, the company had recently introduced a new work organization and new working procedures for disturbance handling and improvement work at the studied production cell. The improvement activity group was called TPM or TPM-team in case B.
The preconditions for having improvement activity groups in terms of one group per shift team was not possible, since each shift only consisted of one operator. Instead, the TPM-team was multi-functional consisting of the operators, the maintainers, the production engineer, the process planner, the quality engineer, the machine designer, the production manager, and finally the maintenance manager – who conducted the meetings. The operators were supposed to run the TPM-meetings and TPM-activities, but this was not the case. However, it was the operators who communicated what had to be improved in production and why, and then the production manager gathered the required expertise for the next TPM-meeting. The improvement work was mainly regarded as the planned TPM-meetings that were held every other week during about two hours each time. Some personnel were, however, aware of the need of operative time for improvement measures between the meetings as well. A constantly high production pressure made it difficult to find time to work with improvements activities as well as for preventative maintenance. Due to different company specific reasons such as personnel shortage, the weekly maintenance activities had not been prioritized during the two years prior to the case study. Motivating factors to participate in the TPM-meetings for the operators, which had to work overtime due to the shift form, were mainly social factors, i.e. primarily to meet other operators to exchange thought and ideas, problem measures and solutions.

Information about production disturbances was primarily communicated verbally, either informally or formally, between the involved actors. The lack of documented disturbance information made it difficult to work more systematically with long term improvements. However, a software system for automatic registration of disturbance was newly installed in the casting plant/cell, implying a potential for disturbance data registration and processing. The new IT-support system was at the time of the study used for testing and evaluation,
before decisions were made about further investments and installation at the other company plants. The operators used the IT-support system primarily for documenting production disturbances, but also as a foundation for discussions with colleagues and for argumentation for new measures or investments. Engineers and managers used the IT-support system mainly to make statistical summaries.

As mentioned earlier, the human robustness of the production system is very much dependent on the skills and knowledge of each operator. During the time of the case study the operators were educated on robot programming, which aimed at improving the manufacturing efficiency. Communication of ‘right information’ or pragmatic information for proper measures was required by operators. The communication and co-operation between operators and other actors in the organization was vital and could indirectly affect the ‘human robustness’ of the casting cell.

5 Analysis of case study results

A complex and non-robust product design was a problem in case A. Changes in material composition that resulted in production disturbances was another problem. Hence, both the unstable product design and material changes were factors that reduced the technical robustness of the production system.

In case A, the work organization and work methods for the improvement work were formally well organized and promising. For example, improvement work that focused on the bottleneck machine in production started to pay off, as well as the use of the IT-support system for
disturbance registrations. However, some general conditions in terms of a high production pressure, in combination with an undermanned work force, resulted in more acute repair work and less preventative maintenance than required.

Following improvement proposals were suggested in case A:

- Facilitate the communication by determining a common terminology related to disturbance handling and system robustness that are understood by all the participating actors (e.g. disturbance data and key values were not consistently classified and used).
- Use a language vocabulary that are understood by all actors and that facilitates communication and co-operation related to disturbance handling (e.g. key values had similar names or abbreviations and the majority of the personnel had difficulties in understanding the documentation from the software support).
- Educate and train operators and maintainers on technical equipment and software systems used, for improved ‘human robustness’ in relation to prevention and coping with disturbances, but also for utilization of disturbances data and for better bottle-neck analysis.
- Give time and priority to improvement work activities for ‘technical robustness’ of the production system (e.g. a very high production pressure, caused lack of time for preventative maintenance and improvement work).
- Make efficient work plans and preparations of maintenance work (e.g. planned stoppage in production facilitate preventative maintenance and the technical robustness of the system).
- Prepare and communicate information to actors that are affected by changes (e.g. maintainers spent much time working with production problems caused by unspoken changes in raw material).
- Create routines for “capturing of experiences” (e.g. by documenting problems that occur caused by tools changes, production process changes, and material changes).
- Improve documentation routines and the capability between different IT-support systems in order to facilitate communication and co-operation between actors involved in production disturbance handling, e.g. operators and maintainers.

Even if the forum existed in case B for communication and co-operation between the involved actors from the different disciplines, the collaboration had potential to be even more fruitful. Valuable time was spent on the improvement meetings discussing old problems that were not taken care of or solved instead of dealing with the problems at once, making time for discussing new problems instead. An explanation to the long list of unsolved problems may have derived from the lack of time and resources to work with preventative maintenance and improvement measures between the times of the meetings. It could also be a question of how the task actually was approached by both improvement team and management. Lack of economic resources in terms of necessary investments was also an explaining factor that came up at one of the improvement meetings attended. The hierarchical steps in the organization for deciding on investments were here seen as an obstacle in their improvement work.

Results from observations at improvement meetings identified both pros and coins with having a combination of actors with different roles and functions. The team composition was both enabling cross-disciplinary discussions and common problem-solving as well as highlighting hierarchical differences in terms of speaker time and underlying conflicts.

The improvement proposals that were suggested in case A and mentioned above may be regarded as fairly general factors that could be valid also in case B. Thus, a common
language, for better understanding and information sharing, facilitates communication and co-operation between actors from different disciplines. Educated and trained work forces improve the human qualification to handle variation, while preventative and improvement activities improve the technical robustness of the production system. Exchange of experiences and planned changes may additionally increase the robustness of the production system.

6 Discussion and conclusions

For the achievement of a flexible and robust production system, the full potential of technical as well as human resources need to be properly utilized. To be able to utilize the full potential of the technical equipment: available and required quality on material, machines, tools, and spare parts as well as preventative and daily maintenance activities are needed. However, the technical system does not function without human involvement and assistance. Here, utilizing human resources primarily aim at making use of the operators’ experiences and knowledge about changes and disturbances in production. This is relevant in preventative and improvement work when operating production system, as well as when new systems are designed.

In both case A and B the production pressure was very high, resulting in a lack of preventative maintenance. In case A, the instant maintenance or repair caused by a disturbance in production was about 70 percent of the maintenance activities, while the remaining 30 percent consisted of preventative maintenance. The maintenance manager had a vision or goal of the opposite relation, i.e. 30 percent repair work and 70 percent preventative maintenance. In case B, the preventative maintenance was completely missing since two years
time, implicating that all maintenance activities consisted of “fire fighting” and repair work instead of pro-active activities necessary to achieve a robust production system.

The type of forums for communication and co-operation between actors from different disciplines were, however, different in the two studied cases. In case A, the discussion forums were more formalized in order to enhance the strategic work in the organization. In case B, on the contrary, the nearness of actors from different disciplines made the communication and co-operation more operative oriented and the strategic work were absent and almost neglected.

The organization or the personnel within it act according to the information they have – not always according to the ‘reality’. In order to utilize opportunities, you have to be aware of them. Organizations that encourage communication and co-operation will enhance the possibilities for creating a more realistic view of the reality and in turn develop a better awareness and preparedness of predictable and unpredictable changes and how to cope with them. Hence, by establishing conditions that facilitates co-operation and communication between different actors in the organization, the flexibility and the robustness of the production system will be improved.

References


