Chapter 3
Focused Flexibility in Production Systems

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Abstract Manufacturing flexibility is seen as the main mechanism for surviving in the present market environment. Companies acquire systems with a high degree of flexibility to cope with frequent production volume changes and evolutions of the technological requirements of products. However, literature and industrial experience show that flexibility is not always a well-defined concept. Therefore it is really complex to understand and use flexibility during system design process. Indeed, the development of structured approaches to support the system design by considering basic flexibility forms is still an open issue. This work presents an Ontology on Flexibility aiming at providing a standard method to analyze flexibility. Firstly, it contributes in systemizing the large number of existing flexibility definitions and classifications. Secondly, it can be used to analyze real systems and to better understand their characteristics in terms of flexibility. Finally this ontology represents a key point of a general approach to design production system with the right level of flexibility.

Keywords Focused Flexibility Manufacturing Systems (FFMSs), Manufacturing system design, Ontology on Flexibility

3.1 The Importance of Manufacturing Flexibility in Uncertain Production Contexts

Companies producing mechanical components to be assembled into final products produced in high volumes, in order to remain competitive, must deal with critical factors such as: tight tolerances on the parts, short lead times, frequent market changes and pressure on costs (Matta et al., 2000; Tolio, 2008). Obtaining optimal-
ity in each of these areas can be difficult and companies often define production objectives as trade-offs among these critical factors (Chryssolouris, 1996).

The flexibility degree of a manufacturing system represents a critical issue within the system design phase. On the one hand, it is considered a fundamental requirement for firms competing in a reactive or a proactive way. On the other hand, flexibility is not always a desirable characteristic of a system. This point needs to be clarified since in many cases flexibility can jeopardize the profitability of the firm. It is rather frequent to find in the literature descriptions of industrial situations where flexible manufacturing systems have unsatisfactory performance (Koren et al., 1999; Landers, 2000), cases where the available flexibility remains unused (Sethi and Sethi, 1990; Matta et al., 2000), or cases where the management perceives flexibility more as an undesirable complication than a potential advantage for the firm (Stecke, 1985).

From the scientific perspective, focusing the flexibility of a production system on the specific needs represents a particularly challenging problem. In fact, the customization of system flexibility provides economical advantages in terms of system investment costs, but, on the other hand, tuning the flexibility on the production problem reduces some of the safety margins, which allows decoupling the phases of manufacturing system design (Tolio and Valente, 2008). One of the key issues is that focused flexibility asks for a very careful risk appraisal. To reach this goal all activities ranging from the detailed definition of the manufacturing strategy to the configuration and reconfiguration of production systems must be redesigned and strictly integrated, thus highlighting the need of combining and harmonizing different types of knowledge which are all essential to obtain a competitive solution.

### 3.1.1 Focused Flexibility Manufacturing Systems – FFMSs

The simultaneous need of flexibility and productivity is not well addressed by available production systems, which tend to propose pre-selected types of flexibility to introduce in the system. Traditionally, rigid transfer lines (RTL) have been adopted for the production of small families of part types (one or few part types) to be produced in high volumes (Koren et al. 1998). Since in RTLs scalability is low, RTLs are usually designed according to the maximum market demand that the firm forecasts to satisfy in the future (volume flexibility); as a consequence, in many situations RTLs do not operate at their full capacity since their designed volume flexibility is frequently over-sized. On the other hand, flexible manufacturing systems (FMSs) and parallel machine-FMSs (PM-FMSs) have been adopted for the production of large mixes of parts to be produced in small quantities (Grieco et al., 2002; Hutchinson and Pflughoeft, 1994). FMSs are conceived to react to most of the possible product changes. The investment to acquire a FMS is very high and it considerably affects the cost to produce a part. Indeed their flexibility is frequently too large and expensive. This is extremely evident for instance in the case producers