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Concurrent Engineering of Machine Parts Production Using Steel Bars and Wires

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Abstsract

The concept of Concurrent Engineering (CE) is explained. For speedy and efficient development new steels and parts, it is necessary to apply CE. Some examples of CE application are introduced in this paper.

Concurrent engineering (CE) is defined as "an approach whereby processes, such as planning, research, design, and production, do not exit in series along the time axis, but stand on the same foundation from the outset of the planning stage, proceed cooperatively and in parallel toward goals while exchanging information, and finish end products."[1] This concept has been put into practice since ancient times when man first created tools, and in itself constitutes nothing new[2]. Concurrent engineering is said to have existed naturally before its high-growth period in Japan[3]. As the division of labor and specialization advanced, and information flow became serialized, researchers in the United States began to study the Japanese way of manufacturing. In the 1980s, the United States advocated the concept of concurrent engineering and succeeded in shortening the development lead time via this discipline. Japan imported the concurrent engineering technique back from the United States, and Japanese companies applied concurrent engineering to their simultaneous design and production with some results[4].

In the manufacturing processes that cover design and assembly, parts, and material industries, like the production of machine parts from steel bars and wires, information mostly flows serially in only one direction from the design side, and concurrent engineering across the different industries is only partially implemented.

Today, technical problems are assuming ever increasing difficulty. There are few examples in which technical problems can be solved in terms of only materials, fabrication methods, or design shapes. Now that most of the technical problems must be solved using a combination of these elements, total concurrent engineering that transcends the different industries has become urgent. As worldwide simultaneous product development and recycle-based design are in demand today, the importance of concurrent engineering, embracing even the eco-business, has increased more than ever.

When attention is focused on the fact that the effects of the physical and chemical treatments applied to materials in all processes after melting and casting are entirely transferred to final machine parts, concurrent engineering can be regarded as engineering concerning materials. In this sense, material engineers must recognize the extremely important obligations imposed on them.

CAD and CAE systems will become an indispensable means for the communication of concurrent engineering across the different industries, with the objective of total concurrent engineering, including personnel exchange. Prompt action is expected to become an important key to the survival of Japan's manufacturing industries.

Examples of technology development belonging to concurrent engineering are given below.

(1) Development of high-strength gears

Gears parts are of such importance that they have come to symbolize machines, and are of great technical depth. This is because gears intermittently transfer high power as a means of power transmission and are accompanied by severe friction. Given the many gears used in transmissions, their downsizing had been long sought as a natural requirement. Designers proposed a smaller module as a noise reduction measure. As flank surface fatigue became a problem, new materials were developed to solve the problem, and gear manufacturers induced residual stresses by shot peening to prevent flank surface fatigue. These measures were combined to accomplish much higher gear strength. The problem of pitting or the failure of gear surfaces to withstand friction under high contact pressure then occurred. The pitting problem accentuated the importance of problem solving by all personnel concerned with design, manufacture, and materials in terms of the gear contact ratio, slip ratio, material chemistry, machining conditions, heat treatment, and other factors. This is a typical concurrent engineering project and no solution would have been possible with conventional serial information flow.

(2) High-strength parts with delayed fracture resistance

The delayed fracture of metals is likely to occur, mainly due to hydrogen, in the middle of machine usage. This means that

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hydrogen must be controlled with due care. When adopting parts that continuously carry tension, for example, high-strength bolts, it is necessary that the design department should restrict the operating environment (corrosion and temperature) and set the tightening torque; that the control and manufacturing departments should avoid sharp radii in the root of the threads and below the neck of the bolts and should ensure complete hydrogen removal after the plating process; and that the material manufacturing department should develop a material with low hydrogen susceptibility and present a maximum permissible hydrogen limit. A serious risk occurs if any one of these steps is missing. It is essential to make the most of concurrent engineering to attain still higher strength.

(3) Hot-forged micro-alloyed steel parts

To eliminate the use of heat treatment, hot-forged automotive undercarriage parts are made predominantly from vanadium-micro-alloyed steel that precipitation hardens on cooling after forging. For the commercial application of the vanadium-micro-alloyed steel, the designers are required to present the degree to which the toughness value of the steel is allowed to deteriorate and to alleviate stress concentration. The production department is required to control the working temperature and cooling rate and to limit the amount of working. As far as the material is concerned, it is necessary to ensure desired toughness, fatigue strength and machinability and to remove harmful elements. In either case, a far higher number of problems than encountered with the conventional quenching and tempering processes must be solved. It is crucial that these problems should not be addressed separately but should be gathered and solved in the best possible manner.

(4) High-strength non heat-treated steel bolts

High-strength bolts are partly produced by a process that eliminates heat treatment by making use of work hardening of steel wire as it is drawn to size. To implement the process, the design department should not become overly preoccupied with material standards like JIS. Since the wire stock is cold headed into bolts, some reduction in toughness and ductility is unavoidable, and it is necessary to relax shape tolerances and service conditions. The boltmaking department must tolerate some reduction in tool life because the tools work high-strength steel. The steel supplier adjusts the chemical composition, low-temperature rolling, rapid cooling, and reduction in cross-sectional area in drawing wire while satisfying the strength, toughness and permanent elongation requirements from the design department and the reduced deformation resistance requirement from the boltmaking department. These efforts combined to commercially produce high-strength non heat-treated steel bolts, but it took 10 years until usage became widespread. This time could have been halved if the CE technique was applied.

Total CE is exploited in may other applications, but has not achieved sufficient results. It is proposed that the design, manufacturing, and material departments should work more closely together to find many more applications for concurrent engineering.

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