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Evolution of Japanese Automobile Manufacturing Strategy Using New JIT: Developing QCD Studies Employing New SCM Model

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Abstract

This paper introduces New JIT that contributes to the evolution of Japanese automobile manufacturing strategy. We believe that the key to successful global manufacturing is joint task team activities between the manufacturer and affiliated/non-affiliated suppliers employing Strategic Stratified Task Team Model. To realize this, we create the New SCM Model for strengthen of SCM. Here, we introduce typical research examples of how this model improved the bottleneck problems of worldwide automobile manufactures.

Keywords: New JIT strategy; QCD studies for automobile manufacturing; New SCM model

Introduction

Toda's management challenge of manufacturer is to provide high QCD (Quality, Cost, and Delivery) products ahead of competitors through "Market creating" activities, with priority given to customers. To accomplish manufacturing that places top priority on customers with a good QCD and in a rapidly changing technical environment, it is important to develop a new production technology and establish new process management to enable global production. For the automobile manufacturing industry, the key to success in global production is systematizing its management methods when modeling strategic SCM (supply chain management).

This paper analyzes and proves the significance of strategically employing New JIT, new management technology principle at Japanese automobile manufacturing Amasaka [1-3] In the implementation stage, automobile manufacturers endeavoring to become global companies are required to collaborate with not only affiliated companies, but also with non-affiliated companies to achieve harmonious coexistence among them based on cooperation and competition called "Japan Supply System" Amasaka [4,5]. To realize manufacturing of excellent quality for customer, we employ the Strategic Stratified Task Team Model" utilizing two core models: Structured Model of Stratified Joint Task Teams and Strategic Cooperative Creation Team Model for strengthen of SCM strategy [6].

Concretely, we create the New SCM Model consisting of three core models: Strategic Task Team Model, Global Partnering Model, and Simultaneous Fulfillment of QCD Approach Model. In typical research examples, we verify the effectiveness of New SCM Model by Total Task Management Team activities between automobile assembly maker and suppliers through the solution of the bottleneck problems of the world wide automobile manufactures Amasaka [7-9].

Importance of Strategic QCD Studies

Progress of Japanese automobile manufacturing industry

The leading Japanese automobile management technology that contributed most to worldwide manufacturing from the second half of the 20th century was the Japanese Production System. This is typified by the Toyota Production System (TPS) Ohno [10]. This system has been further developed as production systems known as Just in Time (JIT) and Lean Systems (Doos et al; Hayes and Wheelwright [11]; Womack and Jones [12]; Taylor and Brunt [13]. The history of such development is shown in Figure 1, "Transition in Management Technology," (Amasaka [14,15].

As seen in the diagram, the Japanese manufacturing represented by Toyota Production System constitutes the basis for the manufacturing carried out worldwide today. Among the main administrative management technologies that have contributed to the development of Japanese manufacturing are Industrial Engineering, Operations Research, Quality Control, Administrative Management, Marketing Research, Production Control, and Information Technology. These are shown on the vertical axis of the diagram. On the horizontal axis, a variety of elemental technologies, management methods, and scientific methodologies are arranged in chronological order. Conventional Japanese manufacturing has developed from in-house production to cooperative relationships with suppliers although, since the beginning administrative management technology has become increasingly complicated.

Therefore, the current task of today's manufacturing sector is to succeed in global production. A key to this is the deployment of supply chain management on a global scale that encompasses cooperative business operations even with overseas suppliers, and the ever growing need for the systemization of such operation methods. In particular, during the implementation stage the organically combined use of partnering and digital engineering (CAE, CAD, CAM), and SCM will become necessary as they are essential for the deployment of the main components of Toyota Production System, called Just in Time (JIT) and Total Quality Management (TQM). Therefore, in-depth study of the kind of administrative management technology that will be effective even for next-generation business operations is also urgently needed.

In recent years, however, both developed Western nations and developing nations have advanced the study of Toyota Production System and TQM and re-acknowledged the importance of the quality of administrative management technology. They have also promoted

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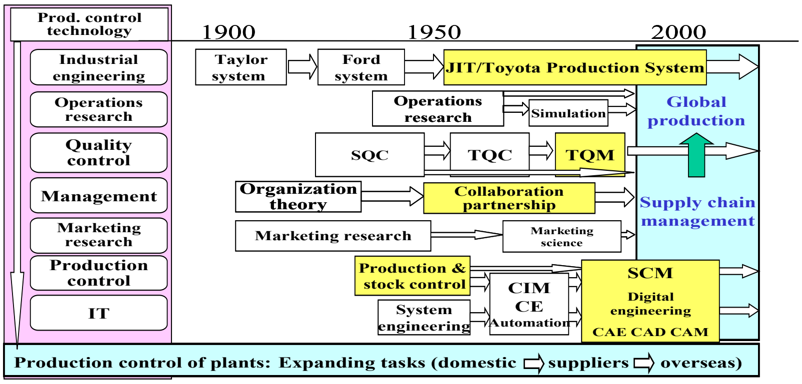

Figure 1: Progress of Japanese automobile manufacturing industry.

the reinforcement of quality in manufacturing on a national level Nezu [16].

As a result of such efforts, the superior quality of Japanese products has been rapidly compromised. One distinctive example of this is shown in a comparison of the quality of automobiles sold in the United States. Although Toyota, still a leading Japanese car manufacturer, can be seen to have achieved steady improvements in the quality of its automobiles (IQS, Initial Quality Study) up to now, GM of the United States and Hyundai of Korea have also promoted quality improvements and achieved even more dramatic results (Amasaka, 2007b, 2008a). The observations above indicate that in order for Japanese manufacturers to continue to play the leading role in the world, it is urgent to reform their administrative management technology from a fresh standpoint, rather than simply clinging to the successful experiences they have enjoyed up to now.

Needs for the reform of Japanese-style management technology

Looking at the recent automobile recall problems, we see a rapidly increasing number of manufacturing quality issues with their roots in technological product design and product (Joiner [17]; Nihon Keizai Shinbun [18]; Amasaka [19,20]. If we are to turn the tide, we cannot be content with simply resolving individual technical issues. Instead, we must evolve core technologies that result in the overhaul of every business process from development and production to SCM, and establish and systematically apply a new management technology model that intelligently links them together Amasaka [21,22]. The top priority issue of the industrial field today is the "new deployment of global marketing" for surviving the era of global quality competition Kotler [23]. The pressing management issue particularly for Japanese manufacturers to survive in the global market is the "uniform quality worldwide and production at optimum locations" which is the prerequisite for successful global production.

To realize manufacturing that places top priority on customers with a good QCD and in a rapidly changing technical environment, it is essential to create a core principle capable of changing the technical development work processes of development and design divisions Amasaka [24]. Furthermore, a new quality management technology principle linked with overall activities for higher work process quality in all divisions is necessary for an enterprise to survive (Burke and Trahant [25]; Amasaka [26]. The creation of attractive products requires each of the sales, engineering/design, and production departments to be able to carry out management that forms linkages throughout the whole organization (Seuring et al. eds [27]; Amasaka [26]. From this point of view, the reform of Japanese-style management technology is desired once again. In this need for improvements, Toyota is no exception Goto [28]; Amasaka [26].

Similarly, it is important to develop a new production technology principle and establish new process management principles to enable global production. Furthermore, new marketing activities independent from past experience are required for sales and service divisions to achieve firmer relationships with customers. In addition, a new quality management technology principle linked with overall activities for higher work process quality in all divisions is necessary for an enterprise to survive Amasaka [29].

Importance of strategic QCD studies with affiliated and non-affiliated suppliers

IT development has led to a market environment where customers can promptly acquire the latest information from around the world with ease. In this age, customers select products that meet their lifestyle and have a sense of value on the basis of a value standard that justifies the cost. Thus the concept of "Quality" has expanded from being product quality, which is oriented to business quality, to becoming corporate management quality-oriented. Customers are strict in demanding the reliability of enterprises through the utility values (quality, reliability) of their products (Evans and Dean [30]; Amasaka [26]. Advanced companies in countries all over the world, including Japan, are shifting to global production. The purpose of global production is to realize "uniform quality worldwide and production at optimum locations" in order to ensure company's survival am idst fierce competition (Doz and Hamel [31]; Amasaka [26].

For the manufacturing industry, the key to success in global production is systematizing its management methods when modeling strategic SCM for its domestic and overseas suppliers. In-depth studies of the Toyota Production System called JIT and Lean Production System, TQM, partnering, and digital engineering will be needed when these methods are implemented in the future. Above all, manufacturers endeavoring to become global companies are required to collaborate not only with affiliated companies, but also with non-affiliated companies to achieve harmonious coexistence among them based on cooperation and competition. In other words, a so-called "feder ation of companies" is needed (Hamel and Prahalad [32].

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New JIT Strategy, Surpassing JIT

Traditional Japanese production system and quality management: JIT

One of the greatest contributions that Japan made to the world is JIT. JIT is a production system that enables provision of what customers desire when they desire it. JIT is also introduced in a number of enterprises in the United States and Europeans a key management technology (Taylor and Brunt [13]; Amasaka [1]. The Japanese-style production system represented by the current Toyota Production System (JIT) is a production system which has been developed by Toyota. Implementing TQM in the production process, this production system aims to achieve the simultaneous of quality and productivity in pursuit of maximum rationalization while recognizing the principle of cost reduction.

This is the essential concept of JIT and therefore, these have been positioned as a core part of Toyota's management technology and often likened to the wheels on both sides of a vehicle Amasaka [33,34]. However, JIT which is representing the Japanese-style production system today has already been developed as an internationally shared system, known as a Lean System and is no longer an exclusive technology of Toyota in Japan. In the Western countries also, the importance of quality control has been recognized through the studies on the Japanese TQM. As a result, TQM activities have been increasingly popular. Therefore, the superiority in quality of Japanese products assured by the Japanese-style quality control has been gradually undermined in recent years [35].

New JIT, New Management Technology Principle

Having said the above, it is the author's conjecture that it is clearly impossible to lead the next-generation by merely maintaining the two Toyota management technology principles, JIT and TQM. To overcome this issue, it is essential to renovate not only JIT, which is the core principle of the production process, but also to establish core principles for marketing, design and development, production and other departments.

The next-generation management technology model surpassing JIT, New JIT, which the author has proposed through theoretical and systematic analyses as shown in Figure 2, is the Just in Time system for not only manufacturing, but also for customer relations, sales and marketing, product planning, R&D, design, production engineering, logistics, procurement, administration and management, for enhancing business process innovation and introduction of new concepts and procedures.

New JIT contains hardware and software systems as the next generation technical principles for accelerating the optimization (high linkage) of work process cycles of all the divisions. The first item, the hardware system, consists of the TMS, TDS, and TPS, which are the three core elements required for establishing new management technology principles for sales, R&D, design, engineering, and production, among others.

The expectations and role of the first principle TMS include the following: (i) Market creation through the gathering and use of customer information, (ii) Improvement of product value by understanding the elements essential to raising merchandize value, (iii) Establishment of hardware and software marketing system to form ties with customers and (iv) Realization on the necessary elements for adopting a corporate attitude (behavioral norm) of enhancing customer value and developing customer satisfaction (CS), customer delight (CD) customer retention (CR), and networks.

The expectations and role of the second principle TDS are the systemization of design management method which is capable of clarifying the following: (i) Collection and analysis of updated internal and external information that emphasizes the importance of design philosophy, (ii) Development design process, (iii) Design method that incorporates enhanced design technology for obtaining general solutions, and (iv) Design guideline for designer development (theory, action and decision-making).

The expectations and new role of the third principle TPS comprise the following: (i) Customer-oriented production control systems that place the priority on internal and external quality information, (ii) Creation and management of a rational production process organization, (iii) QCD activities using advanced production technology and (iv) Creation of active workshop capable of implementing partnership. For the second item, the strategic quality management system, the author is establishing a new principle of quality control; Science TQM Amasaka [36] called TQM-S (TQM by utilizing Science SQC, New Quality Control Principle (Amasaka, 2004c) as a software system for

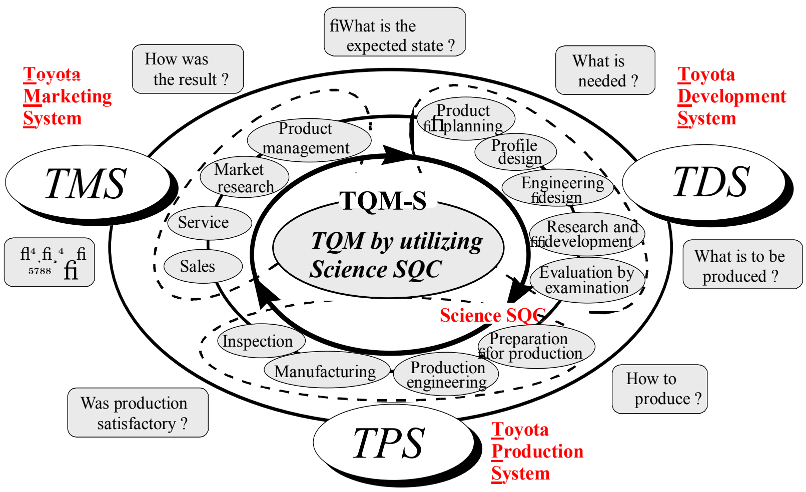

Figure 2: New JIT, New management technology principle.

innovating the business process quality of the 13 departments shown in the diagram (Figure 2).

Strategic Stratified Task Team Model

Japan supply system-partnering chains as the platform-type

As an example, Toyota group consists of a total 14 enterprises Toyota [37] Twelve enterprises, which branched from Toyota Automatic Loom Works, Ltd., form the nucleus of the primary group parts manufacturers (called "Kyohokai") that supply parts directly to Toyota, to which join Hino Motors, Ltd. and Daihatsu Motor Co., Ltd. Each of the group companies is closely linked to Toyota in a wide and solid supplier-assembler relation "Toyota Supply System" called "Japan Supply System" as shown in Figure 3.

An automobile is assembled with some 20,000 parts. Since it is not economical for the assembler to manufacture all the parts in-house, considerable portion of the parts are normally purchased from outside suppliers (parts manufacturers). Therefore, to years, and the situation still remains unchanged for it. If parts purchased from the supplier (parts manufacturer) have low dependability, vehicles assembled with them have also low dependability naturally. This is exactly the reason why "performance of a vehicle almost depends on the parts" (Amasaka, 2000). In this sense, the assembly makers (automobile manufactures) and parts manufacturers (suppliers) are the inhabitant of the same fate-sharing community. Actual supplier-assembler relation is generally quite complex and many-sided.

Relationship between Toyota and its suppliers is unique in many points compared with those of other assemblers. There is the saying that "Toyota wrings a towel even when it is dry", indicating Toyota's strict demand to supplier s for their prices and quality. At the same time, no other assemblers are as enthusiastic as Toyota in raising strong suppliers through education and training. As early as in 1939, Toyota established its basic concept of the purchasing activities for promoting coexistence and co-prosperity.

To realize this, Toyota strengthened its suppliers by making it a rule to continue transaction forever once started. No other assemblers have their supplier groups as powerful as those of Toyota. The 14 Toyota group companies form the nucleus of the powerful supplier system. As thus far stated, close relation between Toyota and its group members is quite cooperative in one sense while simultaneously very competitive in another. This represents the supplier- assembler relation unparalleled elsewhere.

There is no denying that the strength of Toyota that can keep on supplying popular vehicle model such as "Lexus" of high dependability originates from within Toyota's own. But it is also the fact that part of Toyota's strength comes from the strength of its supply system consisting of Toyota group and thousands of other suppliers or Toyota's skill in managing such powerful supply system. In the following, the authors intend to zero in on Toyota's quality management activities in exploring the secret of the strength of Toyota that continues to manufacture vehicles of high dependability. This is because it is quality management activities themselves that provide important bonds to cooperation or partnering between Toyota and its group companies.

Platform-type partnering chains by structured model of stratified joint task teams

Concretely speaking, the author believes that a company has to (i) join forces with domestic suppliers to enhance the intellectual productivity of plant divisions, and (ii) succeed in "global production" to promote overseas operations and develop local production. In the implementation stage, first, (A) the quality management theory of "Science SQC" Amasaka [9] will be applied, as the figure shows, as the methodology for scientifically solving problems through the strategic linkage of these 3 core elements.

Second, as Figure 4 shows, (B) the structured model of stratified joint task teams formed from partnering linkages will be developed systematically and organizationally to promote the strategic development of New JIT This model will consist of Task 1 to Task 8 teams involving the group, department, division, field, whole company, affiliated companies, non-affiliated companies, and overseas affiliates.

As indicated in the figure, the level of problem-solving technology rises strategically to product development strategy I and II through joint task teams of intra-company departments and divisions (Task-1 to Task-5, Task team, Task management team, and Total task management team) in proportion with the improvement of the stratified task level. This technology is further expanded to quality management strategy I to II through the domestic joint task teams of affiliated and non-affiliated companies and overseas counterparts (foreign groups: affiliated/non-affiliated) (Task-6 to Task-8, Joint A to Joint C).

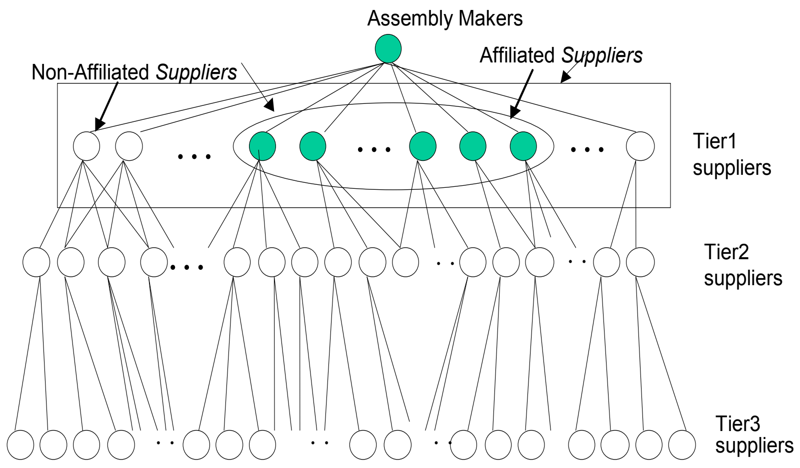

Figure 3: Japan supply system.

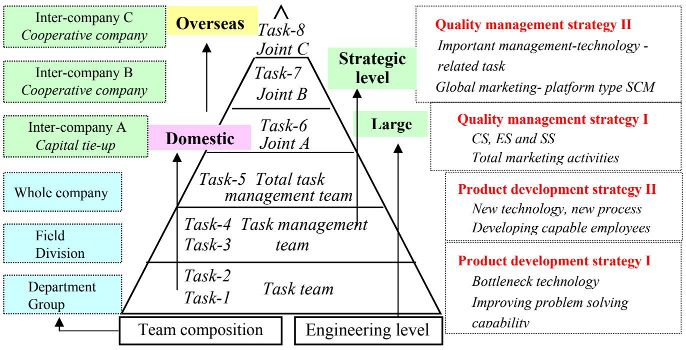

Figure 4: Structured model of strategic stratified joint task teams.

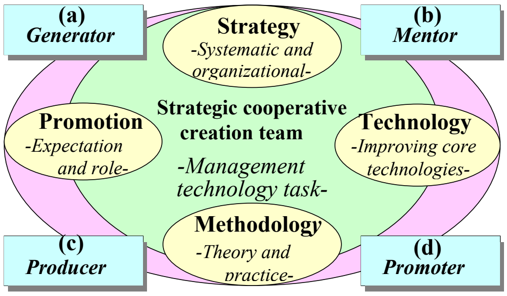

Figure 5: Strategic activity frame of the cooperative creation team model.

Task 6 (Joint A) is aimed at establishing a collaboration with the group suppliers with whom inter-company A has a capital tie-up and Task 7 (Joint 7) is aimed at a collaboration with suppliers that are not within its group. The mission of Task 8 (Joint C) is to strengthen cooperation with overseas suppliers as a strategic alliance.

Construction of the strategic cooperative creation team model

In order for the strategic stratified task team created in Figure 4 to perform New JIT and solve issues of management technology, formation of the Strategic Cooperative Creation Team Model indicated by Figure 5 is essential Yamaji [38]. To empower the team, team members should collectively have the capabilities of (1) "Strategy" for systematic and organizational activities, (2) "Technology" to improve core technologies, (3) "Methodology" to practically identify the gap between theories and the actual, and (4) "Promotion" to fulfill the expectations and roles of the team. If the task team tackles a strategic issue requiring high technologies, the members have to be ingenious enough as (a) "Generators" and at the same time they have to be able to perform strategic analysis as (b) "Mentors".

In addition, to infuse effective drive force in the team activities, creativity as (c) "Producers" and leadership to orchestrate all members' ideas as (d) "Promoters" toward target achievement is important. As the key to the successful team activities, the team leader (Administrator) should select the members who have at least one of the capabilities for (a) to (d), commission authority and responsibilities to the members, and have himself/herself concentrate on risk management. For this reason, as the leader, a person who has an experience of clearing business obstacles should be appointed, so that the leader is capable enough to lead the team overcoming difficulties.

Creation of New SCM Model for QCD Studies Employing New JIT

Today's management challenge is to provide high QCD products ahead of their competitors through "Market Creating" activities, with priority given to customers. This is the mission of New JIT. To realize manufacturing that provides excellent quality to the customer, the author has created New SCM Model with three core elements as follows; (i) "Strategic Task Team Model" between the manufacturer and affiliated/non- affiliated suppliers, (ii) "Global Partnering Model" for strategically implementing New JIT, and (iii) "Simultaneous QCD Fulfillment Approach Model" for developing New JIT.

Strategic Task Team Model" between the Manufacturer and Affiliated/Non-affiliated Suppliers

We believe that the key to successful global production is joint task activities between the manufacturer and affiliated/non-affiliated suppliers as stated above. In other words, it is important for the companies involved to work hard together in world markets under the principle of "harmonious coexistence through cooperation and mutual competition" in order to establish improved management technologies.

An example of concrete measures for development is "Strategic Task Team Model between the manufacturer and affiliated/ non-affiliated suppliers" as shown in Figure 6. To purchase the necessary parts, it will be important for the manufacturer to mutually cooperate with (a) Supplier I (in-house parts maker (own company)), (b) Supplier II, affiliated manufacturer (capital participation), (c) Supplier III, non-affiliated manufacturer, and (d) Supplier IV, manufacturer with foreign capital. In the stage of actual implementation, it is important to strategically organize the stratified task teams from the following viewpoints and by setting the objective to be continual improvement of management technologies: (i) Product strategy, (ii) Engineering strategy, (iii) Quality strategy, (iv) QCD effect, (v) Value of the task teams, and (vi) Human resource strategy.

After solving the most important management technology challenges at the beginning, the important job for the manufacturer's general administrator is to select jointly from his own company and suppliers: (1) "Generators" gifted with a special capacity for creating ideas, (2) "Mentors" having the ability to give guidance and a dvice, (3) "Producers" with the capability to achieve and execute, and (4) "Promoters" capable of implementing things as an organization.

Global Partnering Model" for Strategically Implementing New JIT

Understanding the need for strategically implementing New JIT by applying the aforementioned Strategic Task Team Model between the manufacturer and affiliated/non-affiliated suppliers, we create the 4-core structured "Global Partnering Model (GPM)" in Figure 7 that implements Science SQC. This principle has been proven effective in strategically solving management technology problems in this author's previous studies. As shown in the figure, GPM is composed of four cores, namely (1) Stratified joint task team (GPM-HT, Task-1 to Task-8 by New JIT) in mutual cooperation with affiliated and non-affiliated suppliers, (2) Stratified education training for improving the skills of staff and managers (GPM-HE, the Hierarchical Education by New JIT), (3) Stratified leader training (GPM-HL, the Hierarchical Leaders Growth by New JIT) and (4) Overseas study system (GPM-SA, the Studying Abroad System by New JIT).

To render the created "Global Partnering Model" effective in the implementation stage, it is important to adopt the hardware system with three core elements (TMS, TDS and TPS), and the software system (TQM-S).

Simultaneous QCD Fulfillment Approach Model Developing New JIT

In recent years, leading manufacturers in Japan have been deploying a new production strategy called "globally consistent levels of quality and simultaneous global launch (production at optimal locations)" in order to get ahead in the "worldwide quality competition", and "high quality assurance in manufacturing - simultaneous achievement of QCD" Amasaka and Sakai [39,40]. This is the key to successful global production, and has become a prerequisite for its accomplishment developing New JIT.

However, it has been observed that, despite the fact that overseas plants have the relevant production systems, facilities, and materials equivalent to those that have made Japan the world leader in manufacturing, the "building up of quality - assuring of process capability (Cp)" has not reached a sufficient level due to the lack of skills of the production operators at the manufacturing sites. Under such a circumstance, there are many studies abroad for globalization (Lagrosen [41]: Ljungström [42]; Burke et al., [43]; Hoogervorst et al. [44].

In order to realize the key to global production, considering the importance of scientific quality management, and on the basis of the "New JI T" which has verified the effectiveness of the "stratified task team", the authors create the "Simultaneous QCD Fulfillment Approach Model" for developing New JIT as shown in Figure 8 by Yamaji [45].

The function of the (i) Quality Assurance (QA) and TQM promotion as corporate environment factors for succeeding in "global production are (1) Customer Satisfaction (CS), ES (Employee Satisfaction), and SS (Social Satisfaction), (2) High Quality assurance, (3) simultaneously achieve QCD, (4) success in global partnering. Intellectual productivity and (5) Evolution of quality management.

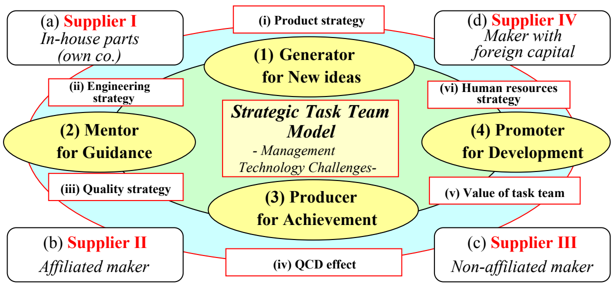

Figure 6: Strategic task team model between maker and affiliated/non-affiliated suppliers.

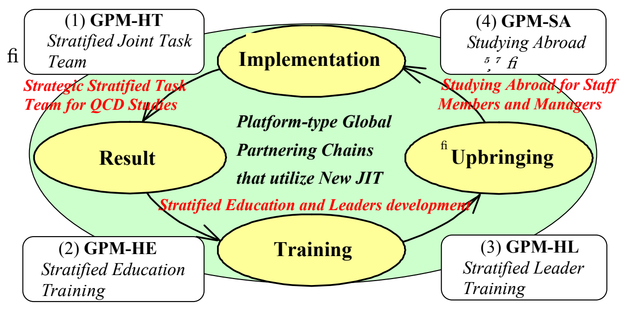

Figure 7: Global partnering model for strategically implementing new JIT.

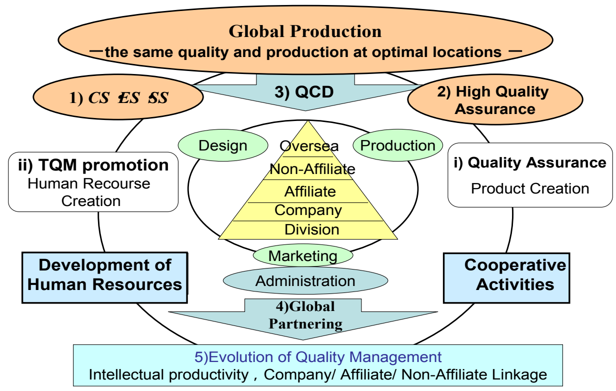

Figure 8: Outline of simultaneous QCD fulfillment approach model.

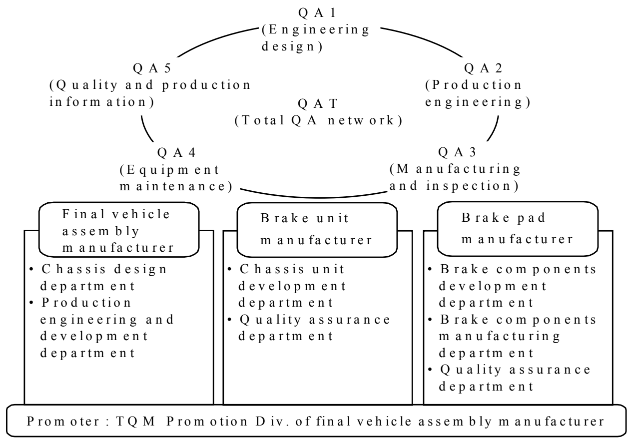

Figure 9: Organizational outline of total task management team.

More specifically, the (i) QA division needs to promote manufacturing of high reliable manufacturing, and cooperative activity across the organization is indispensable to achieve that. In the (ii) TQM promotion division, it is important to cultivate human resources that have even higher skills, knowledge, and creativity. Therefore, the value of intelligent human resources must be promoted in an effort to improve the productivity of white collar workers.

In order to realize the above, global partnering which enables a strategic cooperation among divisions, such as designing, production, marketing and administration as well as the entire company, affiliated companies, non-affiliated companies, and overseas corporations, must be achieved. Improvement of intellectual productivity is simultaneous achievement of QCD utilizing this model.

Application examples employing new SCM model

In this section, we present examples showing the results of research and effectiveness where the "New SCM Model" employing Strategic Stratified Task Team Model mentioned above has been applied in current bottleneck problems, braking performance, transaxle oil seal leakage, and others.

Brake Pad Quality Assurance

Disk brakes work on a principle that the pressing of pads to the rotors by the calipers generate braking force. Brake noise is generated when the pad and the rotor are in contact with each other in a delicately unstable condition. The condition that allows noise or abnormal sound to be generated with ease and the response quality of brake are items contrary to each other. Therefore, it is important to analyze the properties of pads and the response quality of noises and brake, and reduce dispersions in the properties of pads that affect the generation of noises and the braking effect Miller [46].

The key point of this activity lies in establishing technologies that make sensitivity analysis of factors on the braking effect and noise in the aspect of design engineering, and to make these mutually contrary braking performances compatible with each other through bi-directional interaction with the manufacturing engineering.

Total Task Management Team Using Three Pillars of Total QA Network

To establish an organizational system that allows the vehicle design, parts design, production process design, manufacture, inspection, maintenance, sale (service, marketing quality) divisions including these of automotive manufacturer to share know how and information supports engineers' conception. This links to the improvement of technology and improves the quality of business process. Here, this organization is realized in the form of a "Total Task Management Team" by final vehicle assembly manufacturer, brake unit manufacturer, and brake pad manufacturer as shown in Figure 9.

Five teams were formed, which consisted of QA1 (Engineering design), QA2 (Production engineering), QA3 (Manufacture and Inspection), QA4 (Facility Maintenance) and QA5 (Quality and Production information).

These five teams mutually cooperated in developing Total QA Network (QAT) (Amasaka, 2012). As a key technology of quality assurance activities, we create here three pillars of management namely "Total Technical Management (TM)", "Total Production Management (PM)" and "Total Information Management (IM)". QAT activities are implemented by fusing the three total management in Figure 10 into one.

Total technical management

Makes a sensitivity analysis of dispersion in both raw materials and the process condition for the brake response quality and the brake noise, and reviews the engineering method and clarifies process condition control items.

Total product management

To realize the process conditions and control items, divisions such as development, production design, production engineering, manufacturing, maintenance, and quality assurance all combined carry on production activities using the "QA Network" table Kojima [47] of manufacturing based on the matrix diagram method and the process FMEA (Failure Mode and Effect Analysis), and FTA (Fault Tree Analysis), etc. utilizing QFD (Quality Function Deployment).

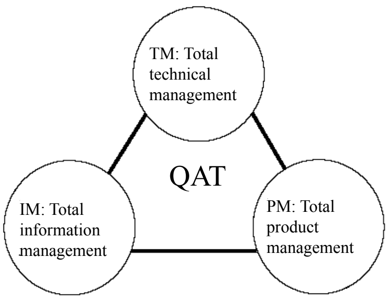

Figure 10: Three total QA network management activities.

Total information management

Establishes a system for making a timely feedback of the market quality information (dealers), following process information (completed vehicle manufacturers) and self-process information (parts manufacturers) to the process.

Development of Total QA Network using SQC Technical Methods

To promptly optimize the Total QA Network systematically and organically, the "SQC Technical Methods" which is popularly used as the "Mountain-Climbing for Problem-Solving" utilizing Statistical Science as shown in Figure 11 is applied. Various types of arrows in the figure represent team activities of QA1 through QA5 respectively.

Total technical management activities

Makes analysis on each material (Figure 11, TM1), conducts a market survey (Figure 11, TM2), and makes factorial analysis on the basis of the above results (sensitivity analysis), boiling down the material to a short term. For example, in the factorial analysis I (Figure 11, TM3), it is found, by using the principal component analysis and other, that in the raw material characteristics, stratified mineral particle size and the diameter of inorganic fiber are related with the noise and friction characteristics as shown in Figure 12. Area "a" represents an area where the noise and friction are in considerably bad condition, while area "b" representing an area where the effect remains. We found area "c" where the both characteristics are not contrary to each other.

We have found through the factorial analysis I that variation of the

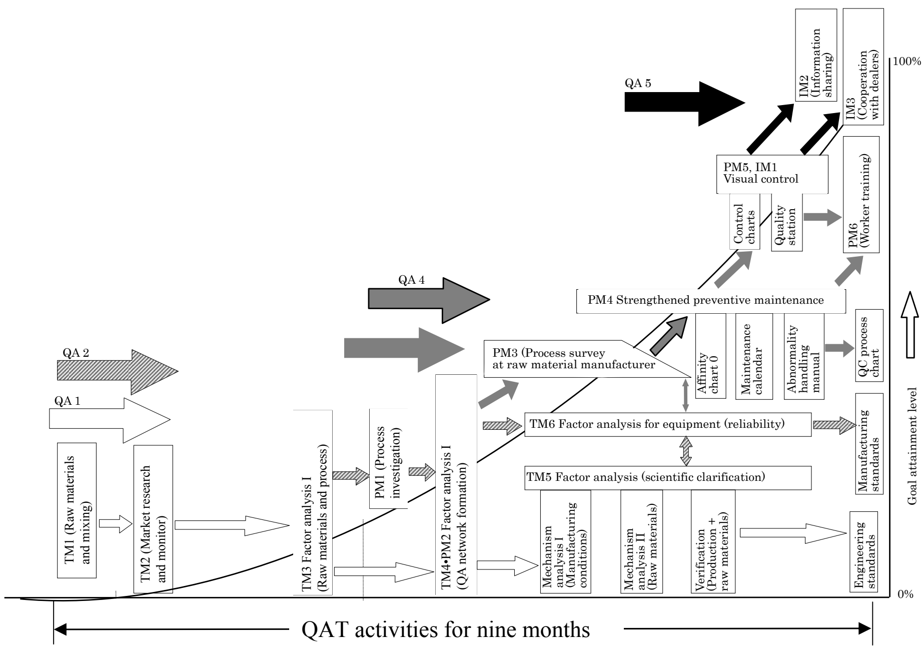

Figure 11: Development of total QA network using SQC technical methods.

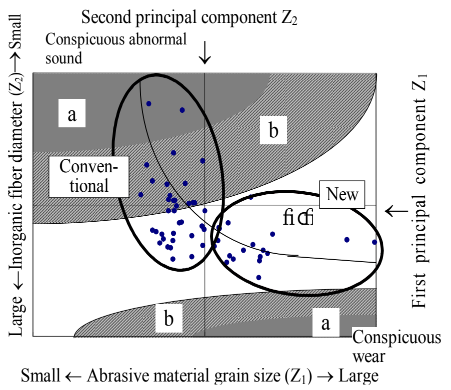

Figure 12: Example of analysed influences of raw material properties.

process and manufacturing conditions (Figure 11, PM1) is important. With regard to ground components (inorganic fibers and hard fine particles), we verified the factorial effect in combination with a technical analysis of a single material and the state of dispersion in the pad through the electron microscope observation. The authors were thus able to clarify the mechanism of variation of the braking effect caused by manufacturing dispersion of inorganic fibers. This led to a successful improvement in cooperation with the material manufacturers.

On the stage of production preparation, the drawings of the product were created using the QA Network table of engineering (Figure 11, TM4) according to the market quality. The drawings of the equipment were created using the QA Network table of manufacturing (Figure 11, PM2) on the basis of quality of conformance. On this stage, we boiled factors down to important factors, which are related to the acceptance of raw materials and the management of the condition and state of manufacturing process.

In addition, we then analyzed phenomena on respective factors selected (Figure 11, TM5). We grasped the equipment condition quantitatively to optimize tolerance in the product drawing scientifically. For example, by using unbalanced regression plotting, we came to understand that the thermoforming temperature and the substitute characteristics of the braking noise are in causal relation as shown in Figure 13.

Each area "a" represents an area where there is the lack of strength or an area not suitable for the forming while area "b" representing an area having residual effect of the lack of strength or unsuitableness for forming. Considering the strength and formability, we decided on Area "c" for the management condition of thermo-forming process. To retain the management condition of area "c", we implemented a factorial analysis on the side of the equipment (Figure 11, TM6). For example, we made a factorial analysis of dispersion in the temperature of the forming dies. This enabled us to provide the uniform pad forming temperature.

Total product management

To realize the process conditions found through "Total Technical Management", factors for non-conformance were investigated with the process survey (Figure 11, PM1) and association

With quality characteristics was determined with the "QA Network" of manufacture (Figure 11, PM2). Moreover, to complete the "QA Network", a brake unit manufacturer, a brake pad manufacturer and raw material manufacturer formed a task team, for instance, to carry on quality review mutually (Figure 11, PM3).

As the result, present process capability became known. This developed to the prevention of defect and flow-out of defectives, then to the strengthening of preventive maintenance (Figure 11, PM4: Preventive maintenance calendar), visual management (Figure 11, PM5: In line SQC), Worker Training (Figure 11, PM6: Manual for measures of abnormal quality).

Total information management

We quality check station (Figure 5, IM1), which readily provides process information as the result of the "Total Product Management". Moreover, we established routes by which market information (DAS; Dynamic Assurance System) Sasaki [48] held by the completed vehicle manufacturer can be shared by parts manufacturers (Figure 5, IM2) and the route by which actual parts information can be acquired from dealers (Figure 5, IM3).

At present, we are summarizing the market information, process information, engineering information and other quality information of QA1 through QA5. We promote to upgrade the pad performance and quality by analyzing the above-mentioned information. In addition, we wish to state that the scheduled development of wide QCD studying activities by both companies realized given results where market claim was reduced to one-sixth and under.

Effect

Through practical use of Total Task Management Team, the effect of the QCD research activities is remarkable as follows;

*Estimated market claim ratio reduction to 1/6 (from 2.6% to 0.4%) *In-process fraction defective: down 60% (from 0.5% to 0.2%) *Short convergence of initial failures: (from 9 months to 3 months) *Cost reduction: 9.4% (156 Yen/unit)

High Reliability Assurance of the Transaxle Oil Seal Leakage

The oil seal for the drive system works to seal lubricant inside the transaxle unit. The cause and effect relationship between the oil seal design parameters and sealing performance is not necessarily fully clarified. As a result, oil leakage from the oil seal is not completely eliminated, presenting a continual engineering problem (Lopez et al. [49]. So far, oil seal quality improvement has been made as follows; a development designer having empirical engineering capability

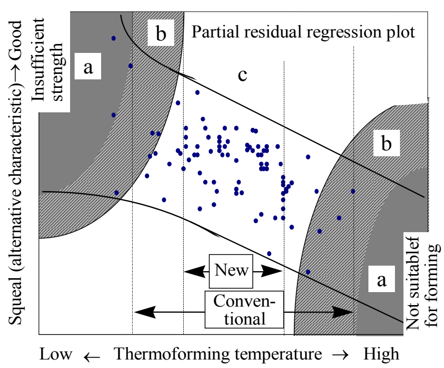

Figure 13: Causal Relation between alternative characteristic of squeal and thermoforming temperature.

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recovers the leaking oil seal parts from the market, analyzes the cause of leakage with proper technology, and incorporates countermeasures into the design.

Many of the recent leaking parts, however, exhibit no apparent problem and the cause of the leakage is often undetectable. This makes it difficult to map out permanent measures to eliminate the leakage; Nozawa et al. [50].

Dual total task management team

Effective solution of technical problems requires the formation of teams and understanding of the essence of problems by the teams as a whole. To ensure high reliability of product design and quality assurance, a Total Task Management Team involving final vehicle assembly manufacture with transaxle unit (T company), and oil seal manufacturer (N company) personnel was created to transform the implicit knowledge (relating to product and processes in both organization) into explicit knowledge and to create new technology of interest to both organizations. The Dual Total Task Management Team named "DOS-Q" (Drive-train Oil Seal-Quality Assurance Team: T DOS-Q5 and N DOS-Q8) is shown in Figure 14.

"T DOS-Q5" constituting teams comprise Q1 and Q2 in charge of investigation into the cause of the "oil leakage" and Q3-Q5, which handled manufacturing problems relating to drive shafts, vehicles and transaxles. Similarly, "N DOS-Q8" formed teams Q1 through Q8. Q1 and Q2 at T Company interacted closely with their counterparts at N company to improve the reliability of the oil seal as a single unit and, likewise, Q3-Q8 handled the manufacturing problems for quality assurance.

Accordingly, the teams shared their individual knowledge (relating to empirical techniques and other technical information) to apply them to solving the problems under consideration. Each team had a general manager and the joint team was led by T Company's TQM promotion general manager for the vehicle reliability assurance. The methodology of TDS-D (Total Design System for Drive-train Development) involving TM (Technology Management), Pm (Production Management), and IM (Information Management) was used by utilizing "Three Total QA Network Management Activities" as the above Figure 10.

Moreover, to realize optimization of the "DOS-Q5" business process, problem solving is formulated using the "Development of Total QA Network using SQC Technical Methods" by using the same approach as the above Figure 11.

Fault analysis and factorial analysis

In the conventional cases of oil seal unitary sample collection process, it was from time to time observed that there was available no information on the mating part or the collected sample was attached with foreign matters which hampered the determination of the cause of leakage. To prevent this, recovery process was improved along with the acquisition of the background or the history of the market recovery. Thus Weibull analysis could be made in Figure 15 with credibility based on the comparison result with the actual parts by recovering non-defectives as well as defectives or by recovering whole of the trans-axle unit in order to reproduce oil leakage.

As the result, we have obtained a new knowledge that the failure type of "oil leakage" is a mixed model of three failures of the "Decreasing failure rate", "Constant failure rate" and "Increasing failure rate" which was not found in th e rule of thumb. Moreover, we could understand correct particle size distribution and composition of foreign matters attached to the oil leaking parts by recovering them in a special recovery case. It was also newly discovered that two oil seals of apparently similar degree of wear produce difference in pumping quantity depending on the mileage.

For the factorial analysis to researching the oil leakage phenomenon and mechanism of the failure type, not only defective parts (oil leaking parts) but non-defectives (non-oil leaking parts) were used. As the result, the difference of two parts was detected through the discriminating analysis as shown in Figure 16. For example, It is known that the factor analysis to the design factor of hardness of oil seal rubber has the largest influence among explanatory factors evaluated. The result agrees with the experience technology.

Such survey and analysis could not be made with the conventional separate investigation activities of the vehicle manufacturer or the parts manufacturer. This was accomplished through the "Total Task Management Team" activities between the companies of T and N.

Clarification of oil Leakage mechanism by visualization

We have arranged the information obtained from the above-mentioned activities, which have boiled down to the following new

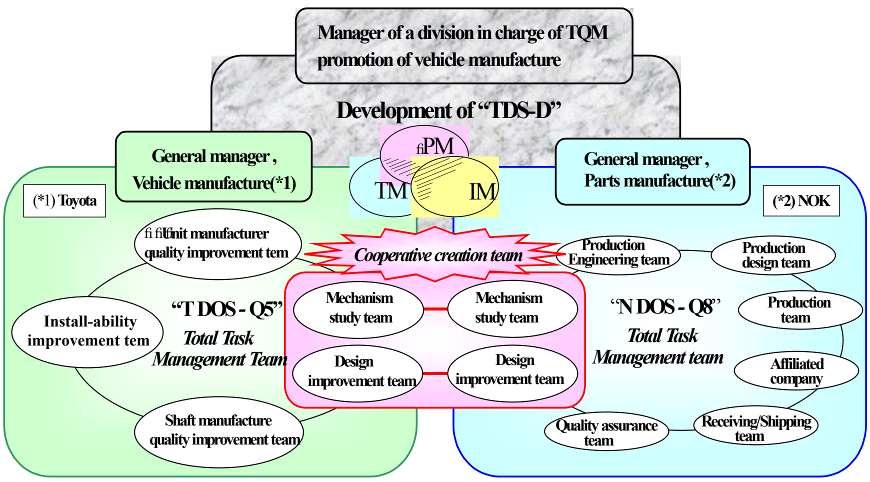


Figure 14: Configuration of cooperative creation team (Total task management team).

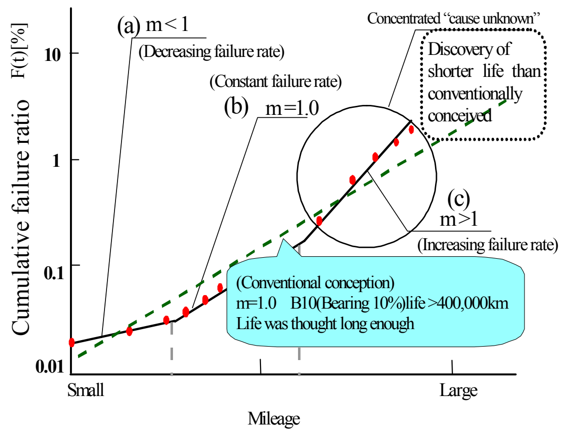


Figure 15: Result of Weibull analysis.

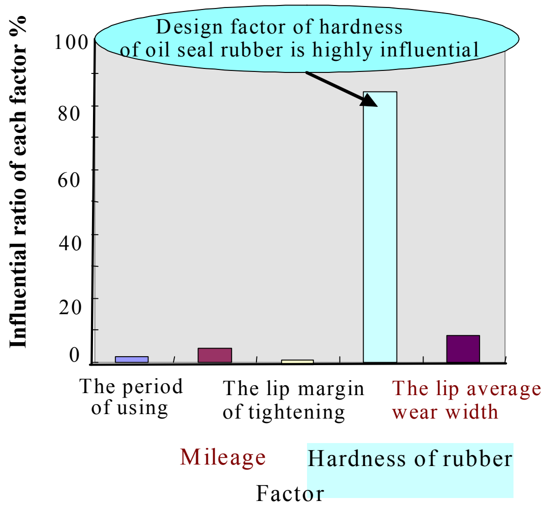


Figure 16: Influential effect of each factor.

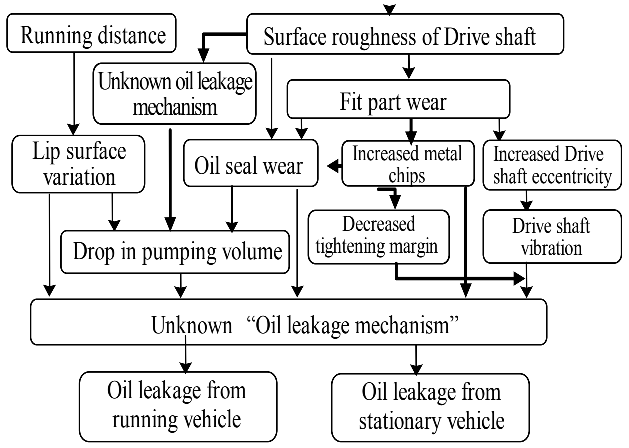


Figure 17: Estimated oil leakage mechanism.

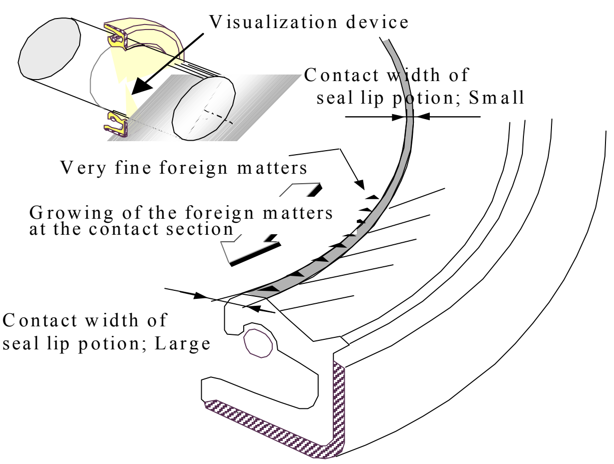
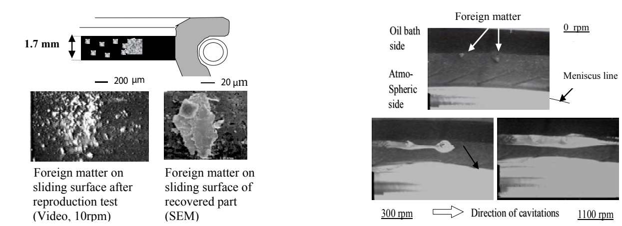


Figure 18: Oil leakage mechanism (Test-1).



(i) Growing of the Foreign Matter (Test-2) (ii) Causing Cavitation (Test-3)

Figure 19: Oil leakage mechanism (Test-2 and Test 3).

facts : (1) When compared the recovery parts with the forced wear parts, sealing performance differs because of the difference in the lip surface condition, (2) Sealing performance drops if the axis has greater surface roughness. On the basis of such findings and the quantitative analysis data, the team generated another affinity and association diagrams concerning oil leakage and estimated the oil leakage mechanism to discover the presence of "unknown mechanism" as shown in Figure 17.

Accordingly, a device was developed to visualize the dynamic behavior of the oil seal lip to turn this "unknown mechanism" into explicit knowledge as shown in Figure 18 and Figure 19. As the result of observation of the recovered parts from the market with this visualization device, a process was observed by which very fine foreign matters which were conventionally thought not to affect the oil leakage grow at the contact section (Test-1 and Test-2). As a result of the component analysis, it is confirmed that the fine foreign matter is the powder produced during engagement of gears inside the transaxle gear box.

These fine foreign matters are piled on the microscopic irregularities on the lip sliding surface to bring changes to the microscopic pressure distribution eventually degrading the sealing performance. Also the presence of a mechanism was confirmed from a separate observation result that foreign matters that had bitten into the lip sliding surface caused the aeration (cavitations) to be generated to the oil flow on the lip sliding surface to deteriorate the sealing performance (Test-3). As far as the authors know, such knowledge was not given consideration conventionally and only discovered through the current team activities.

Applying optimal CAE design approach model

We address the technological problem of oil seal leakage in automotive drive trains as a way to construct an "Optimal CAE Design Approach Model" for quality assurance. The model is used to explain

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cavitation caused by the metal particles (foreign matter) generated through transaxle wear, a pressing issue in the automobile industry.

Oil Simulator Using Highly Reliable CAE Analysis Technology Component Model

We used the knowledge obtained from the visualization experiment to logically outline the faulty as the above “(3) Clarification of Oil Leaka ge Mechanism by Visualization”. This was done in order to capture the problem using the Highly Reliable CAE Analysis Technology Component model as shown in Figure 20. Using this process, the author was able to arrive at a hypothesis for why the cavitation was occurring; namely, factors like low pump volume and seal damage had compromised the tightness of the seal and lead to oil leaks.

As the figure indicates, the designs are optimized by integrating several aspects of the calculation process, including problem (root cause) identification, conceptualizing the problem logically, and calculation methods (precision of calculators). Once the root causes of the problem are identified, it is critical that there is no discrepancy between the mechanism described and the results of prototype evaluations.

The visualization experiment revealed that cavitation was occurring due to a weakening of the oil seal in areas (surfaces) that were in contact with the rotating drive shaft. This weakening was causing oil seal leaks. The Rayleigh Plesset Model for controlling steam and condensation was used as a CAE analysis model that could explain the problem.

The finite element method and non-stationary analyses were used as convenient algorithms. The Reynolds-averaged Navier-Stokes equation, Bernoulli’s principle, and lubrication theory were appropriate theoretical formulas. Accuracy was ensured, and the time integration method was used to perform calculations in a realistic timeframe. Each of the above elements was used to construct the Oil Seal Simulator.

CAE Analysis Examples

A cavitation is generated at the following steps; Oil collides with a foreign substance - the flow velocity rise near a foreign substance - the fall of pressure - decreased pressure is carried out to below saturated vapor pressure - emasculation of oil - generating of a cavitation as shown in Figure 21. This analysis results at a rotation speed of 1100 rpm.

(i) The fluid speed analysis was then conducted in order to look more closely at the mechanism causing cavitation. The analysis revealed that rapid changes in fluid speed were occurring in the vicinity of foreign particles, and that fluid speed drops immediately before the oil collides with foreign matter. This led to the conclusion that the presence of foreign particle was having an effect on oil flow.

(ii) Comparing cavitation and the fluid speed analysis results against the results of the pressure analysis reveals that in areas of reduced pressure, oil was disappearing inside the cavities being formed meaning that drops in pressure e were likely being caused by these concave areas.

(iii) Cavitation analysis confirmed the cavitation occurring around foreign matter, thus replicating the results of the visualization experiment. At the same time, the finding that cavitation becomes more significant as the rotation speed of the drive shaft increases was similarly replicated.

Verification and Consideration

The above CAE analysis allowed, we to clarify the faulty mechanism causing cavitation; namely, the presence of metal foreign particles was affecting the strength of the oil flow, causing drops in pressure in areas

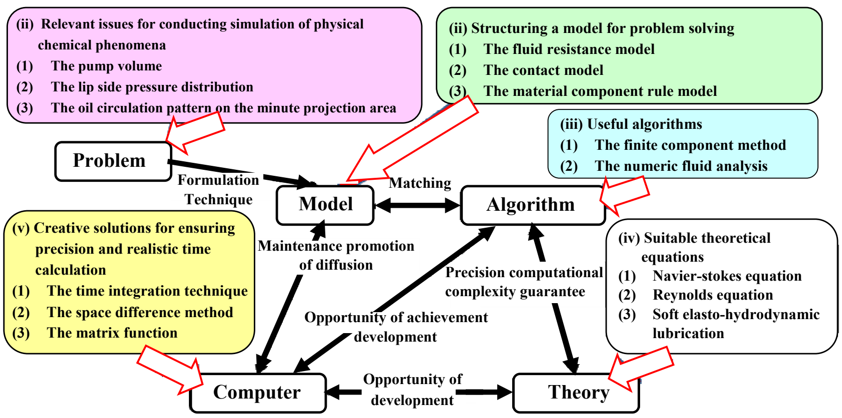
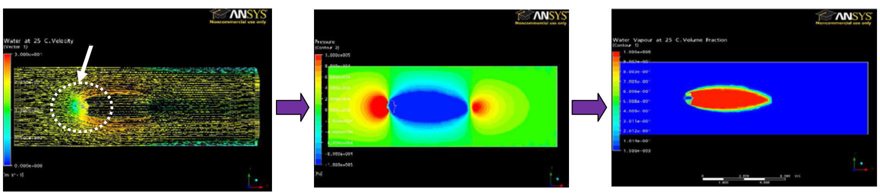


Figure 20: Oil seal simulator using highly reliable CAE analysis technology component model.



(i) Fluid Speed Analysis (ii) Pressure Analysis (iii) Cavitation Analysis

Figure 21: Cavitation analysis around foreign matter.

with faster oil flow and creating cavities. In addition, a similar analysis of changes in the shape and size of the foreign particles revealed that these changes were also causing changes in cavitation. These CAE analysis results indicate a close link between particle size/shape and cavitation.

Preproduction and testing/evaluation of prototypes add a significant amount of time and cost to the development process. However, precise CAE allowed manufacturers to eliminate preproduction (as well as prototype testing/evaluation) and still predict the mechanism causing cavitation and oil leaks. Though gaps such as minute surface variations caused by foreign particles and the shape of the oil film model exist, the CAE analysis allowed the authors to recreate the changes in flow speed and pressure around the foreign metal particles that were causing cavitation - changes which typically cannot be identified.

The deviation between the CAE analysis results and the results of the prototype testing were less than 5%, attesting to the usefulness of precise CAE analysis in certain cases.

Design Changes and Process Control for Improving Reliability

These results led to two measures to improve design quality (shape and materials): (1) strengthen gear surfaces to prevent occurrence of foreign matter even after the B10 life (L10 Bearing to MTBF) to over 400,000 km (improve quality of materials and heat treatments), and (2) formulate a design plan to scientifically ensure optimum lubrication of the surface layer of the oil seal lip where it rotates in contact with the drive shaft.

The result of these countermeasures was a reduction in oil seal leaks (market complaints) to less than 1/20th their original incidence as shown in Figure 22. We believe that this research result will contribute to period shortening of the development design and simultaneous fulfillment of QCD greatly from now on.

Application to Similar QCD Studies

We were able to apply the New SCM MODEL to critical QCD studies of automobile manufacturing using New JIT strategy, including predicting and controlling the special characteristics employing Strategic Stratified Task Team as follows; (i) Preventing vehicles' rusting (ii) Intelligence production operating system (iii) Simultaneous fulfillment of QCD for improving automotive chassis

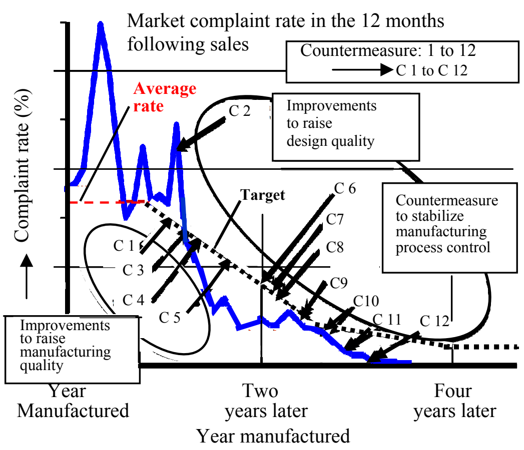


Figure 22: Reduction in market complaint rate.

(paint corrosion resistance and welding process), (iv) Automobile Body Color Development Approach Model Muto et al. [51] (v) prevention of bolt looseness (Hashimoto et al., [52], (vi) New Global Partnering Production Model, (vii) New Turkish Production System and New Vietnam Production Model (Siang et al., [53]; Miyashita [54] and (viii) joint task team activities between Toyota Motor Corporation and Toyota Motor Thailand.

Conclusion

Today's management challenge of manufacturer is to provide high QCD products ahead of competitors for the market creating. The current task of today's Japanese automobile manufacturing is to succeed in global production by evolution of manufacturing and SCM between the assembly makers and affiliated/non-affiliated suppliers. To realize this, we developed the Strategic Stratified Task Team Model with the Structured Model of Strategic Stratified Joint Task Teams, and Strategic Cooperative Creation Team Model by employing New JIT.

Concretely, we created the New SCM Model consisting of the Strategic Task Team Model, Global Partnering Model, and Simultaneous QCD Fulfillment Approach Model developing Strategic Stratified Task Team Model. By applying the created New SCM Model, we could illustrate the effectiveness of strategic QCD studies on current bottleneck problems, braking performance, transaxle oil seal leakage, and many others.

In the future, New JIT will be positioned as "new principle of next-generation manufacturing" of worldwide production management technology strategy, and applied to solving various practical problems utilizing New SCM Model.

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