The Applications of Concurrent Engineering in Powertrain Development

Ruiping Wang
Zhejiang Geely Holding Group Ltd., Ningbo, China
1. Why CE

Traditional Development Mode

- **Project Mechanism**
  "Research → Supply → Production → Sale"
  - **Advantage**: sub procedures have sufficient input. Small risk in Project Management.

- **Project Management**
  Single emphasis in different stages, easy to manage

- **Organization Structure**
  Clear divisions, low overlap and less association
  - **Disadvantage**: long development cycle, easy to lose market opportunity

- **Development Cycle**
  Relatively long development time

---

Vehicle owned/1000 persons in 2002-2011

- The auto ownership per thousand capita:
  China: 60 VS. North America: 800
  - Still broad market in China;

- Increasingly stringent regulations for fuel consumption and emissions;

- Diversified and personalized market demand;

- Short lifetime of products, fast upgrading;

---

Sales of Auto in China Market from 2000-2011

- New Products launched from 2000-2012

www.geely.com
2. Characteristics of CE

Definition of CE

➢ Design, purchasing and process conducted concurrently, integrates from conceptual design to detailed design, trial manufacture, manufacture, sale and after-sale service;

➢ prompts to innovate, optimize process continuously, improve quality, reduce cost, shorten development cycle and strengthen competitive power.

---

4 essential ingredients of CE

Synchronism

➢ All functional team work simultaneously;
➢ Fast response and feedback.

Convergence

➢ Multidisciplinary discussion :
➢ Optimized solution from many possibilities.

Comprehensiveness

➢ All stakeholders know the overall picture;
➢ Individual complies with the group, high consistency.

Cooperativeness

➢ Cooperative spirit :
➢ Active team-work awareness among stakeholders ;
2. Characteristics of CE

Convergency

D&D
3-5 solutions meeting the func demand.

Manufacturing
Due to manufacturability and cost, narrow down to 2-4 solutions.

Purchasing
Pre-select 2-3 suppliers capable for the required technology. Also take into account mass production, cost and timing.

Supplier
Fix supplier and start detailed design.

Optimization Theory and Critical Path method imbedded in CE

O=F+M+Q+T+C

O - Optimized Solution
F - Function
M - Manufacturing
Q - Quality
T - Time
C - Cost

Stakeholders specialized in their own subjects, CE takes accounts all contributions and needs, and is an effective way to find the best fit.
2. Characteristics of CE

**Advantages of CE**

- Product Quality meets customer expectation to win the market;
- Shorten the product development term from 4-5 years to 2-3 years.
- Reduce the D&D cost over 1/2

3. CE Implementation

**Implementation foundation of CE**

- Effective organization structure
- Detailed CE plan
- Explicit R&R
3. CE Implementation

**Organization Structure**

- **Project Management**
  - **Product R&D**
  - **Purchasing**
  - **Manufacturing**
    - **HR**
    - **Quality**
    - **Finance**
    - **Legal**
  - **Supporting Matrix**
  - **"Big House" Structure**

---

**3. CE Implementation**

**R & R**

**CE within multi development layers**

<table>
<thead>
<tr>
<th>Dept Stages</th>
<th>Sales</th>
<th>D&amp;D</th>
<th>Purchasing</th>
<th>Manufacturing</th>
<th>Finance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Research</td>
<td>R</td>
<td>S</td>
<td>I</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>BENCH MARK</td>
<td></td>
<td></td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Cost analysis</td>
<td>S</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cylinder Block team RASIC Sheet for X Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task</strong></td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Cylinder Block 3D Design</td>
</tr>
<tr>
<td>Supplier pre-selection</td>
</tr>
<tr>
<td>Manufacturability analysis</td>
</tr>
<tr>
<td>Trial production</td>
</tr>
</tbody>
</table>
3. CE Implementation

Development Flow and Plan

Conventional development flow: Series development

<table>
<thead>
<tr>
<th>Planning phase</th>
<th>Product Design &amp; Development Phase</th>
<th>Parts Purchasing Phase</th>
<th>Process Design Phase</th>
<th>Production Confirm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 3</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 4</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 5</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Development Flow and Plan

Concurrent development flow: Parallel development

www.geely.com
3. CE Implementation

**CE Implementation Process**

1. Preliminary research
2. Concept design
3. Detailed design
4. Design validation
5. Design confirmation
6. Pilot production
7. Mass production

7 phases and 3 function modules (R&D, purchasing and manufacturing).

---

3. CE Implementation

**Preliminary research**

**Sales**

- To cooperate with D&D to do market investigation, customer visit, and make investigation report;

**D&D**

- Participate in market investigation, do benchmark research, and confirm tech. direction according to investigation report;

**Manufacturing**

- To investigate problems happened in the market and plant failure cases;
- To confirm process quality target per design reliability target;

**Purchasing and SQE**

- To do domestic suppliers risk evaluation, estimate purchase cost, confirm potential suppliers;

**Finances**

- To analyze preliminary return on investment, and confirm investment intent;
3. CE Implementation

**Concept design phase**

**D&D**
- Formulate project plan;
- Define design target and concept design data;
- Invite suppliers to attend key technical proposal discussion; to discuss relationship between technical proposal and cost, and purchasing feasibility.

**Purchasing**
- Select suppliers, potential supplier capability evaluation and confirm preliminary suppliers list;
- Make supplier development plans in tiers per project timing plan and parts development timing plan;
- Long lead time and key parts suppliers need to be selected in first tier;

**Manufacturing**
- Evaluate manufacturability and assembly feasibility of concept design;
- Design preliminary process;

---

3. CE Implementation

**Detailed design phase**

**Purchasing**
- Select second tier key parts suppliers;
- Start negotiation, to confirm product cost;
- Participate in supplier parts APQP process;
- Start purchasing of long lead time equipment;

**D&D**
- Confirm product parts 2D drawing and 3D model;
- Compile product DFMEA documents, parts CAE analysis;
- Confirm assembly condition and assembly detail list;

**Manufacturing**
- PFMEA, virtual manufacturing analysis;
- Analyze process feasibility and confirm process proposal;
- Confirm key equipments development and key accuracy checking proposal;
- Detailed process design;
3. CE Implementation

**Design validation phase**

**D&D with Manufacturing**
- Sample validation, including validation of assembly, performance and durability;

**Design/purchase/SQE**
- Ensure sample manufacture progress and quality to avoid delays;
- Onsite monitoring for key parts;

**Manufacturing**
- Attend sample trial assembly and evaluation;
- Purchase equipments;
- Compile production process documents;

---

**Design confirming phase**

<table>
<thead>
<tr>
<th><strong>R &amp; D</strong></th>
<th><strong>Manufacturing</strong></th>
<th><strong>Purchasing/SQE</strong></th>
<th><strong>QA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Confirm product design per testing results;</td>
<td>Equipment manufacture progress management;</td>
<td>Supplier PPAP planning</td>
<td>Approve production line sample assembly;</td>
</tr>
<tr>
<td>Confirm vehicle application of powertrain;</td>
<td>Production line preliminary process capability analysis;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Finish plant construction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. CE Implementation

**Trial production phase**

**D & D**
- Follow up and solve quality and manufacturability problems in trial production;
- Attend supplier PPAP

**Purchasing and SQE**
- Approve supplier APQP activity; supplier onsite review;
- Negotiate outsourcing parts mass production price; sign purchase contracts;

**QA**
- Construct quality assurance system;
- Organize production line approval;

**Production**
- Establish production system;
- Organize production approval activities;

---

3. CE Implementation

**Mass production phase**

**Purchasing/SQE**
- Conduct purchasing after SOP;
- To manage supplier changes;

**Manufacturing**
- To confirm preliminary process rating
- To compile production version process documents;

**D & D**
- Feedback and improvement;

**Production**
- To enhance production organization and management to achieve mass production capability;

**QA**
- Conduct PPAP;

---

www.geely.com
4. Difficulties in Implementation

- Difficult in formulating the project plan
- Insufficient data input
- Contradictions in system matching
- D&D and Purchasing hard to work together closely
- Difficult in selecting production facility type
- Strong leadership needed
- Team work and Cooperative Culture to back up

Solution to implementation Difficulty

- **Difficult in formulating the project plan**

**Issues:**

- Plan compiling inaccurate, with big discrepancy, and of no guiding meaning.

**Solutions:**

- Implant the principle of setting the milestones from up-down and feedback from bottom-top to ensure the rigorous and feasible of plan.
4. Difficulties in Implementation

◆ **Insufficient of data input**

**Issues:**
➢ The work from upstream has not done while downstream needs to start without sufficient data input.

**Solutions:**
➢ Divide the work into several sub tasks, i.e. each sub task’s done, initial data passed to the next sub task. Thus the next task can be started earlier and be carried on concurrently.

---

4. Difficulties in Implementation

◆ **Contradictions for system matching**

**Issues:**
➢ Sophisticated technologies and broad disciplines involved in Powertrain development. Project constrained by inter-module system matching.

**Solutions:**
➢ Transpositional consideration for each others, help to find solutions together.
➢ Overall consideration and balance from higher level managers.
4. Difficulties in Implementation

- **D&D and Purchasing hard to work together closely**

  **Issues:**
  - The development of Powertrain needs to coordinate with parts development, where early involvement of suppliers is critical. The early stage of design always lacks of supplier tech, quality, cost and timing information.

  **Solutions:**
  - At project kick off, purchasing need to join D&D, providing supplier info and grasp development progress.

---

4. Difficulties in Implementation

- **Difficult in selecting production facility type**

  **Issues:**
  - Process development and product design be concurrent is a challenge, especially the selecting production facility type which must be in face of possible design change and design proposal adjustment.

  **Solutions:**
  - Manufacturing should involve the design process comprehensively, reducing the possible change by product process analysis, DFMEA analysis and virtual manufacturing technique.
  - Try best to select standard factory of strong flexible, such as high precision horizontal machining center, and planning various compatible proposal for possible change.
4. Difficulties in Implementation

- *Strong leadership needed*

  **Issues:**
  - CE requires high degree cooperation among each function modules and stakeholders, it creates difficulties in project overall coordination.

  **Solutions:**
  - Specialists who have ample experience in development and good in coordinating shall be appointed as the team leader.

---

4. Difficulties in Implementation

- *Team work and Cooperative Culture to back up*

  **Issues:**
  - To ensure the success of CE, a lot of tasks cross out and intertwine, need good concordance among departments.

  **Solution:**
  - Build up highly cooperative teamwork ambience, achieve seamless connection.
5. Application Cases

Case 1  Concurrency of development & purchase

- One design confirmed by D & D and supplier;
- Purchasing talked with another supplier for mass production. Thus A prototype and B prototype suppliers were different;
- A prototype supplier cost or timing did not comply the need for production, need to change supplier in later phase;
- The new supplier has another plan for parts, so original plan need to change, new tests need to be done. New cost and extra time need to be paid.

Actions:

- Purchasing involved in product D & D in early stage;
- RFOs to suppliers as many as possible, comparing tech and cost;
- Each parts development shall be considered as a sub-project of Powertrain development, not just parts sourcing. Small project management team led by responsible engineer shall be formed.

Case 2  Concurrency between D & D and Manufacturing

- Manufacturing participates project development late;
- D&Ds are lack of manufacturing experiences, or they consider less about process;
- Perfect product design, but bad machining process of parts, big assembly process difficulty, different equipment cycle time and etc will cause delay of product development process.
- For example, one turbo charger assembly time is 5 minutes, but overall production line cycle time is 42 seconds, and this will lead to the problem that mass production cannot be achieved.

Actions:

- Concurrency between process and design from project start;
- D & D attend fully in process evaluation;
- QA joint evaluations to design and process by phases;
- Coordination DFMEA and PFMEA;
5. Application Cases

Case 3  Concurrency between powertrain development and vehicle application

- In traditional development process, various powertrain systems are independently developed;
- In vehicle application process, if interference between intake and exhaust system and pipe line location, design changes happened;
- Cabin interference problems will appear if vehicle application started after powertrain development done;

**Actions:**

- Clear product application planning; clear vehicle model application at beginning of powertrain development;
- Concurrency of Powertrain development and vehicle application;
- Overall layout engineers responsible;
- Virtual assembly in early stage, in time quality gate review.

6. Conclusion

- Many applications prove that CE can effectively reduce development timing, improve quality and reduce cost.
- Problems we encountered maybe is just a tip of the iceberg, experiences we gain is also just a drop of water in the sea.
- As CE concept is accepted by more and more companies, its extensive use is believed to happen.