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# HYBRID IN CONSTRUCTION MACHINERY

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**ABSTRACT**

After second oil shock in 1978, fuel consumption cost has become an important evaluation factor for construction machinery, many improvements have been made to increase machine efficiency[1]. Recent year, as the Kyoto Protocol get effective, further effort on fuel consumption cut or CO2 cut is required for all machine makers. As the success of the hybrid system in automobile, construction machinery makers also put a lot of force on research to apply the hybrid concept in their own machines. This paper introduced the research and development of hybrid machinery in Hitachi Construction Machinery Co. Ltd , and also discussed the problems in this field.

**KEY WORDS**

Hybrid, Construction machinery, Excavator, Wheel loader

## INTRODUCTION

Recently, for purpose of energy saving and green emission, various kinds of HYBRID vehicles are promoted in automobile industry. In construction machinery industry, makers also actively developed various kinds of machines based on hybrid concept[2]. This paper reviewed main features of construction machinery and problems on their hybridizations, and also introduced the development of hybrid wheel loader and hybrid excavator in our company.

## HYBRID in CONSTRUCTION MACHINERY

### Construction Machines and their Application Features

There are various kinds of machines in construction machinery, for example, crawler type machines as excavator in Figure 1(a), crane as Figure 1(b), and wheel type machines as excavator in Figure 1(c), wheel loader in Figure 1(d). When we want to apply the hybrid

(a) Excavator (b) Crawler Crane

(c)Wheel excavator (d) Wheel Loader

Figure 1 Various type of Construction Machinery

concept in each type of machines, the system has to be considered to fit its special working style. Compared with the automobile vehicle, construction machinery has two obvious features[3].

The first one is that the construction machines have multiple actuators. In automobile, a car has only one actuator for driving tires, and a large part of its engine power is prepared for its acceleration; A hybrid car can regenerates the moving energy in braking process, and re-used it for acceleration, so the engine size can be easily cut down, and the fuel consumption can be reduced. But for a hydraulic excavator, it has 6 actuators, e.g. swing, boom, arm, bucket, left and right travelers. According to its working content, sometimes the machine will share the total engine power to several actuators simultaneously, and sometimes, it needs to concentrate its full power to one actuator. The analysis of which actuator consumes more power, which actuator has more potential power to regenerate, and so to downsize the engine power is a quite difficult problem in hybridization of these machines.

Another feature is that the construction machine has to use hydraulic power. No matter what kind hybrid system, it needs a power storage component, such as accumulator, flywheel, battery, capacitor etc. Most machine makers prefer using electrical generator/motor as energy convention component, and battery or capacitor as energy storage component. The rotation actuators, says, motors are relatively easy to be substituted by electrical motors, but until now there is still no electrical device in the world which can substitute the hydraulic cylinder in same efficiency and same compacted size; So a well harmonized hydraulic and electric hybrid system is a practical way in current stage. But for Crawler Crane, all the actuators are in rotated motion, in this meaning, the hybrid based on electrical component will be easy to realize.

Figure 2 shows a simple comparison of power train efficiency for hydraulic and electrical systems. It can be found that for rotation movement, with the substitution of electrical system, at least 10% improvement in efficiency can be expected.

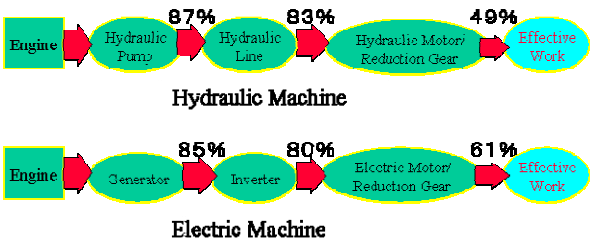


Figure 2 Comparison of the hydraulic and electric power systems

**Example of Hybrid Systems**

For wheel type machines as wheel loader, the power consumed in travel movement takes a large ratio in its total working process, and the wheel driving is easy to be driven by electric motor, the hybrid configure of the this type of machine is relatively clear. And it will be mentioned later in detail.

But for hydraulic excavator, there are multiple pumps to drive multiple actuators, various kinds of hybrid systems are possible. For different kind of hybrid systems, the energy saving effect is list up in Table 1 according to the system simulation.

Table 1 Fuel consumption for different system

| System | Fuel Consumption Ratio |
|---|---|
| 2-pump System (Conventional System) | 1 |
| Serial Hybrid 2-pump System | 1.10 |
| Parallel Hybrid 2-pump System | 0.86 |
| Serial Hybrid 4-pump System | 0.46 |
| Parallel Hybrid 4-pump System | 0.40 |
| Double-pump Regeneration System | 0.43 |
| 4-pump Hydraulic System | 0.41 |

Figure 3, 4, shows the concept figure of some typical systems. It can be found that comparing with standard machine, more than 50% energy saving effect can be expected in some conditions.

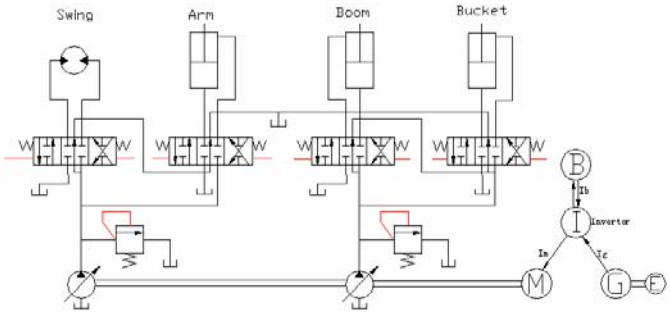


Figure 3 Two pumps serial system

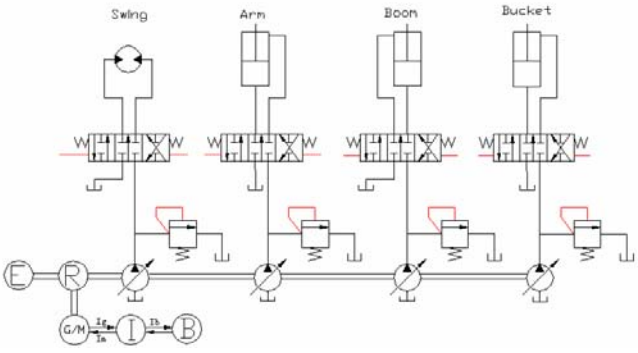


Figure 4 Four Pumps parallel

**Problems in Hybrid Construction Machinery**

Compared with the ordinary automobile, the load change rate and amplitude are much larger. For example, a 20 tons class excavator works in a 30 seconds typical working period, its total load power can be changed 2 or 3 times between 0kw to 60kw.

How to regenerate the energy in this kind of load change is an essential problem in hybrid construction machine. And so large and frequent changing of load power makes the battery or capacitor work in serious condition, how to extend their cycle life time is also a serious problem. And how to control the electrical actuator in quick and precise response under such a serious load process is also a difficult problem.

Construction machinery have to be applicable to all over the world, and all kind of environment condition, components need to have same or even higher capability than automobile on environment performance, for example, as to vibration and impact resistance, automobile need only to resist the vibration about 5-7G, but the construction machinery need to resist more than 10G.

## HYBRID WHEEL LOADER

**System Outline**

Figure 5 shows the system outline of the hybrid wheel loader developed in our company[4]. Engine drives the hydraulic pump and electric generator in parallel, and the pump drives the hydraulic system for working front, and the generator drives electric motor and then the wheel movement. The working front driving uses the conventional hydraulic system, the wheel driving use serial hybrid system.

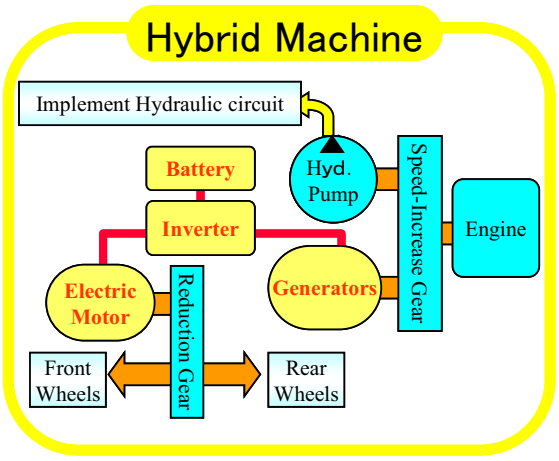


Figure 5 System outline of the Hybrid wheel loader

Since the ratio of traveling in total working process of the wheel loader is quite large, even so the system is simple, it has well effect on power saving

In practice, the hybrid system regenerates the braking energy into electric power and saves it in battery as the wheel loader is in deceleration, and use the power to assist the engine as it is in acceleration. The system can not only uses the braking energy effectively, but also improves engine efficiency in acceleration process.

The most typical task of the wheel loader is V type loading, its working process is shown as Figure 6. In this process, acceleration and deceleration frequency is quite high, the fuel consumption can be largely cu-off with this hybrid system.

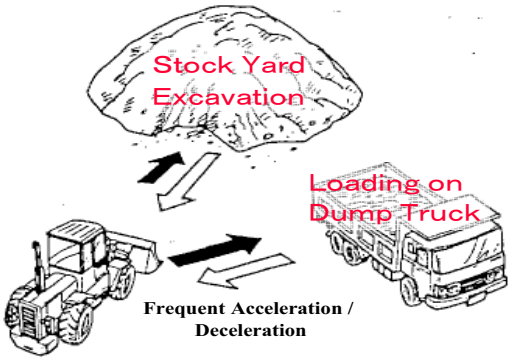


Figure 6 A typical working model of wheel loader

As it described above, the hybrid wheel loader can save the energy mainly in three aspects.

1) Increasing the efficiency of power train by the electrical driving.
2) Optical engine running by electric assistance
3) Power regeneration in deceleration

**Experimental Performance**

Figure 7 shows the picture of the hybrid wheel loader we developed. And Figure 8 shows the performance experiment records. It can be noticed that the energy regenerated in braking process well balanced the power needed in acceleration. And comparing with convention machine with HST system for wheel driving, in piston traveling process the fuel consumption can be cut down by 30-40%, and in total working process the fuel cost can save about 25-30%.

We did not take any changes for front working system in this case, if possible, better effect might be expected.

Figure 7 picture of the hybrid wheel loader

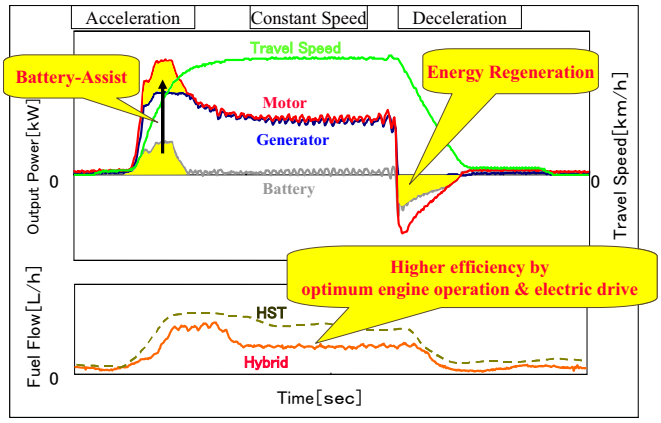


Figure 8 Running test results of hybrid wheel loader

## HYBRID HYDRAULIC EXCAVATOR

### System Outline

Figure 9 shows the system outline of the hybrid hydraulic excavator developed in our company[5].
The front working part, says the boom, arm, and bucket uses hydraulic system, swing uses electric motor to drive. When the swing is braking and boom is lowered down the energy is regenerated and saved in capacitor for assisting the engine on necessary.

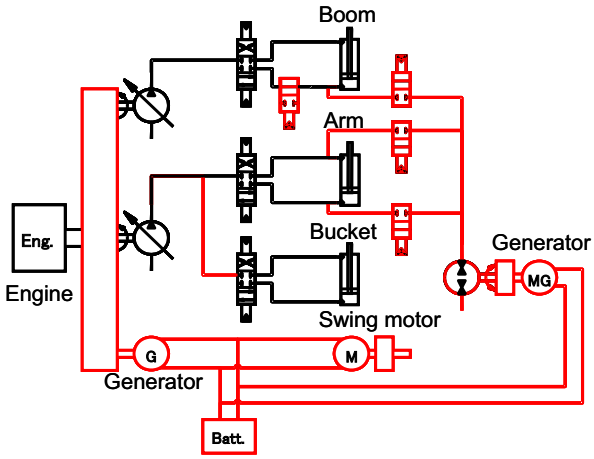


Figure 9 System outline of Hybrid excavator

### Experimental performance

Figure 10 shows the state of machine for digging experiment. From the experiment we knew that compared with standard machine, the hybrid excavator can save the fuel consumption as much as 25%.
In this machine, to keep the total operation performance in same level with standard machine, engine size is not compacted. For some special used machine as its working content is limited in some range, for example, the machine mainly used for handling or moving something, according to the load analysis, the engine size may be cut down, and so better fuel consumption result can be expected.

Figure 10 Picture of hybrid excavator

## CONCLUSION

Since most of construction machines have multiple actuators and the hydraulic cylinder is difficult to be substituted by electric actuators, the hybridization of the machines is not an easy problem to answer. Even so in our practice, with electrical driving of partial system and well arranging of total system, the fuel consumption can be improved by 25-40%.

For reduction of Co2 release, and stopping the earth warming process, we will continue to put effort on hybridization of the construction machinery.

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