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# MODULAR SYSTEM DESIGN FOR PLASTIC EURO PALLETS

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Although pallet, as a tool, yields significant and widely recognized economic effects in production and distribution systems, it is still not fully utilized, indicating that it needs to be defined and developed as a specific product. Euro pallet product was designed using PRO/ENGINEER software system CAD module, as one of the most popular CAx systems, yielding a pallet of novel modular design that meets all the operational requirements of the existing range. The chosen material ensures high pallet longevity and durability, in line with the concept of sustainable development.

*Key words:* design, modularity, euro pallets, plastic

**Dizajn modularnog sutava plastičnih euro paleta.** Paleta kao sredstvo za rad ima izuzetan značaj i poznate ekonomske efekte u proizvodnim i distributivnim sustavima. Međutim, odnos prema paleti kao proizvodu, nije proporcionalan njenom ukupnom značaju. Obrazloženi aspekti neizostavno ukazuju na potrebe definiranja i razvoja palete kao specifičnog proizvoda. Dizajn proizvoda plastične euro palete je izveden u CAD modulu programskog sustava PRO/ENGINEER kao jednog od najpoznatijih CAx sustava. Dobijena je paleta novog modularnog koncepta koja ispunjava sve radne zahtjeve postojećih paleta. Izborom materijala je dobijena dugotrajnija paleta koncepta održivog razvoja.

*Ključne riječi:* dizajn, modularnost, euro paleta, plastika

## INTRODUCTION

Modern product development is market-oriented, and is driven by functional and market product value, as well as factors that determine its design.

Decisions made during the design process are guided by product functionality, whereby the form must meet the user requirements, whilst respecting properties of the materials used. Industrial designers employ visual, creative and intuitive techniques in making their special contribution to the design process [1].

Contemporary market is characterized by a large number of producers of the same type of product. In terms of users' purchasing decision, in addition to functionality, design often plays a major role. In the final product domain, there is a special class of products where functionality surpasses the market requirements.

Thus, significantly lower resources are typically allocated to the design, as these products are used in other manufacturing processes.

Palette is a classic example of the product characterized by functional dominance. The economic viability of the pallet systems is the foundation of the logistics and distribution systems efficiency. Moreover, the final product must meet loading and safety criteria in tough working conditions comprised of loading and transport dynamic cycles, as well as static cycles of storage.

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European Pallet Pool estimated that 300 ÷ 500 million pallets are in regular circulation globally. The rapid increase in the demand is evident in the intensity of their production, in 2006, about 52 million new pallets were introduced to the market. The key issue implicit in the pallet systems is that current product range is dominated by wooden pallets, which are they could be burned, it is one option of energy recovery, and at the same time they are cheap, thus failing to meet the current environmental standards. In contrast, plastic pallets are recyclable and can not only replace their wooden counterparts, but also promote sustainable development [2].

As one pallet is produced per 15 inhabitants globally, the market quantum for this product is enviable. The proportional participation of pallet production phase in the overall process is far greater than for many other products where design tends to dominate. The total quantum of the pallet market is sufficient to justify the initial investment in development, improvement and more intensive use of design in pallet production.

## PRODUCT DEVELOPMENT AND DESIGN

Product development can take two main directions: development of new and improvement of existing products. For new product development, the internal company resources are utilized, in terms of the engineering knowledge base, and external sources of ideas (market information, technical literature, etc.).

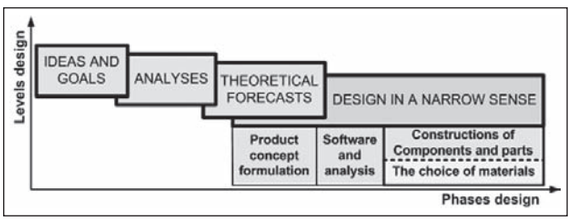


**Figure 1** Product design phases and levels

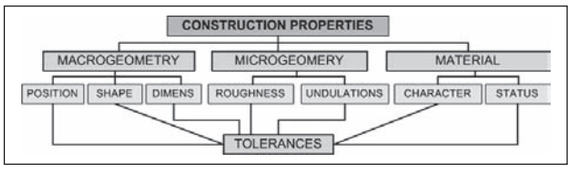


**Figure 2** Structural properties of complex products

In applying some of the methods (production and implemented technological system analysis, cataloguing methods and internet) to generate creative ideas in new product development process, established principles of product development must be followed, namely versatility, integrity, methodical approach, minimum requirements, identity, competitiveness, and modularity [3].

The introduction of any new product must be justified by the market demands, such as market innovation, usefulness, high functionality, aesthetics, competitive price, environmental protection, and recyclability.

Product design, in the narrow sense, which follows the analysis of the ideas, objectives and theoretical forecasts, initiated by market information, includes the phases and levels shown in Figure 1.

In the product structure design that, in general, can be seen in a number of the hierarchical arrangement variants, it is necessary to define the constructional component properties at all complexity levels, as shown in Figure 2.

The aforementioned requirements and tasks that are solved in the process of product design and the final construction modeling are comprised within the technological model, which can be viewed as a constructional and technological product design process.

It is necessary to follow the basic standardization criteria in a systematic and disciplined manner, as well as the quantitative technological elements, such as standardization, unification, modularity, simplification, and specialization.

Modular system design implies combining or assembling products using standard modules.

Modular concept of product development is one of the most creative approaches to product design. It requires a comprehensive analysis of the range of products that are combined based on basic and complex modules and components for their assembly according to the requirements imposed by the product functional structures.

Modular product design effects are particularly evident in the use of suitable CAD systems, where the designed modules are stored in the graphics database.

## SPECIFICATIONS AND DESIGN

In this study, a product was designed using the following plastic materials (thermoplastics) where are the data for material:

- Basic module standard pallet 1200×800×150 (Figure 3),
- Module semi-pallet 600×800×150 (Figure 4) and
- Module quarter-pallet 600×400×150 (Figure 5).

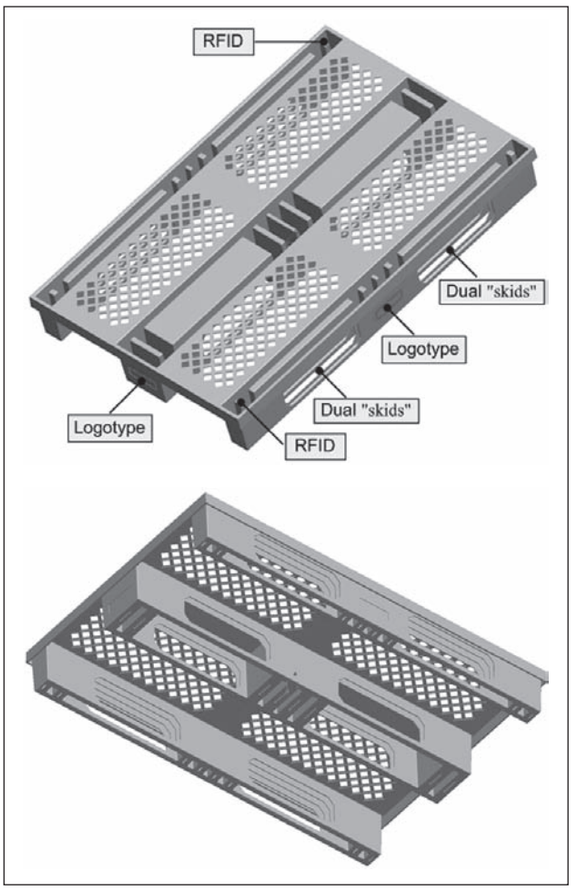


**Figure 3** Standard euro pallet

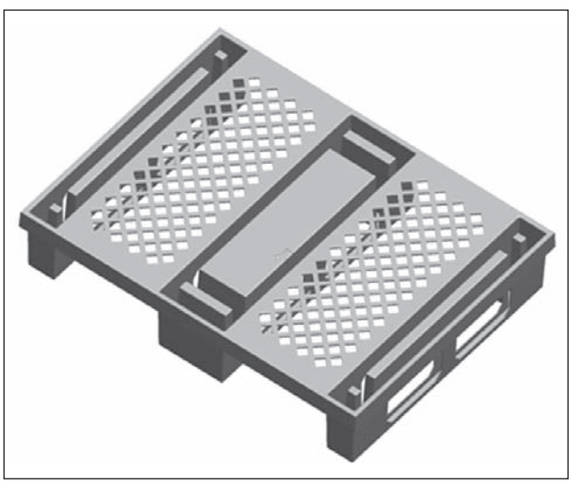

**Figure 4** Semi-pallet

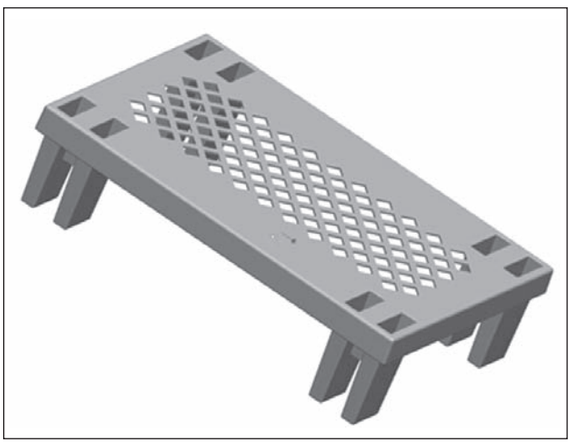

**Figure 5** Quarter-pallet

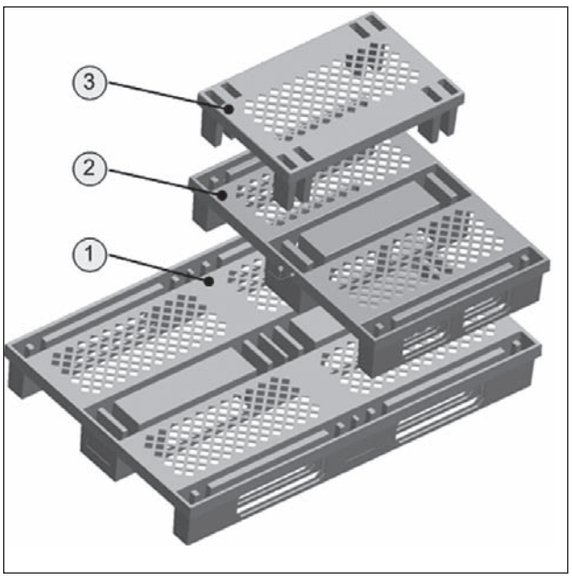


**Figure 6** Product design: 1 – Standard pallet, 2 – Semi-pallet, and 3 – Quarter-pallet

Product design was realized in the PRO/ENGINEER software system CAD module-one of the most popular CAx systems. The conceptual model development specifically focused on the details, such as how can you specific this without knowing of material, the casting angles, curvature radii, etc., related to the development of mould as well as the plastic products, i.e. plastic euro pallet [4].

Product concept was developed on a modular basis with the potential for combining related modules as well as modules of different dimensions (Figure 6).

Basic module 1 – standard pallet can contain two modules 2 – semi-pallets, and four module 3 – quarter-pallets, whilst module 2 can contain two modules 3.

## MATERIALS

The 185 million tons of thermoplastics with wide range of applications produced in 2007. are mostly comprised of different types of polyethylene (39 %), polypropylene (25 %) and PVC (19 %). Furthermore, in the same year, 215 million tons of plastic was utilized globally, of which 85 % were versatile thermoplastics (PE-LD, PE-LLD, PE-HD, PP, PS, PVC, ABS and PET) [5].

The materials most commonly used in plastic pallets are polypropylene (PP) and polyethylene (PE).

PP is a thermoplast with many properties similar to those of high-density PE. However, PP has a higher tensile strength, it is harder and more elastic, as well as more transparent and radiant, with equal gas and vapor permeability.

The PP drawback is its low impact strength, especially at lower temperatures. This disadvantage may be overcome by copolymerization of propylene with other α-olefins-mostly ethylene-which are added in quantities of 5 ÷ 20 %, as well as by inclusion of small amounts of elastomers based on ethylene, propylene and non-congruent diene EPDM (Ethylene-Propylene Elastomers) into the polymer. PP easily forms composite materials with inorganic fillers. Thus, the polypropylene materials are manufactured not only as homopolymers and copolymers with a small proportion of other α-olefins, but also as modified PP with fillers, such as asbestos, glass fibers, carbon fibers, etc. However, in practice, they are differentiated by molecular weight, type and amount of comonomers, additives and fillers, coloring affinity, metallization, etc. [6].

PP finds the widest application as a fibrous material, as well as plastomer.

Polypropylene Glass Fiber Materials (PP-GF) of density 1,14 ± 0,03 g/cm$^3$, High Density Polyethylene (PE-HD) of density 0,941 ÷ 0,960 g/cm$^3$, and their regranulates are materials suitable for making plastic euro pallets.

## SPECIFICATIONS

### Weight/load

The maximum dynamic load for standard and semi-pallet is 1,000 kg and 500 kg, respectively. Their corresponding weights are 14 kg and 7 kg, in line with the new EU directive stipulating the use of lighter pallets in the cyclic processes of daily transportation, storage and manipulation with the aim of reducing the participation of the pallet weight in the total realized material flow.

### Stacking

Pallets are designed to stack in blocks of 26 standard or 54 semi-pallet units, although the number can be increased. Pallets are auto-consolidating and do not require binding during the stacking process. Pallet stacks of arbitrary dimensions provide efficient utilization of transport vehicle or storage capacity and eliminate the need for consolidation operations. Overall, the use of these pallets allows for cheaper and safer empty pallet chains in the logistics processes. All pallets are self-draining, enabling outdoor transport and storage, as well as washing. Pallets do not require special transpor-

tation and storage conditions and are resistant to atmospheric or other aggressive environments (salt, acid, extreme temperatures).

## Compatibility

The modules are mutually compatible, whereby two semi-pallets are mountable on the standard one, two quarter-pallets can fit the semi-pallet and, similarly, four quarter-pallets are mountable onto the standard pallet. Such compatibility enables arbitrary variations in the formation of pallet stack. This feature further enhances the transport and storage conditions of empty pallets, improves dispersive distribution, reduces the cost full pallet reloading, facilitates the participation of smaller transport units in supply chains, increases the choice of finished product packaging modules, improves commissioning, etc. Overall, the achieved compatibility of the basic pallet significantly improves the flexibility of logistics processes and complex requirements of pallet stacking [7].

Moreover, the utilized techniques and materials for securing the products on a pallet are fully compatible (thermoshrink-stretch film, regulary the tapes are made of polyester, etc.).

## Friction

Pallets can be manufactured from various polymeric materials, to meet the customer requirements, which guide the choice of technological procedures implemented in the pallet manufacture. A wide range of polymeric material types enables pallet production governed by the specific characteristics of the working environment as well as the supporting surface friction requirements. The required friction can be achieved through utilizing polymer properties and technological processes of manufacture (mould design and construction) in order to obtain specific pallet bearing surface morphology, which will remain viable during the lifecycle of the pallet.

## RFID/Logo

Pallets can be equipped with diagonally placed RFID tags, in order to achieve automation, identification and pallet flow tracking in the logistics processes. Favorable polymer characteristics facilitate the complete realization of arbitrary design and durability of the pallet manufacturer's, owner's and user's logo.

## Environment/recycling

The pallet material can be fully recycled and reused for production of the same, contributing by up to 80 % in the new product. Moreover, the recycled material can be the basis for euro pallets of new generations. Negligible pallet erosion during the lifecycle, combined with a wide range of recycling applications introduces these pallets into the "green cycles". Using this material for pallet manufacture dispenses with the exploitation of forests, which is a significant contribution to environmental protection.

## Economics

High exploitation efficiency of empty pallets and small weight participation in the formed pallet unit directly define the positive economic effects in energy saving during the working processes.

Indirect positive economic effects stem from the modularity, potential for pallet specialization, reliability and durability, and other aforementioned characteristics that enhance logistics processes. The recycling potential is a new feature that is not comparable with other pallet types, which-in accordance with the current sustainable development trends-justifies the higher initial investment of introducing plastic euro pallets in logistic processes.

# CONCLUSIONS

In developing the conceptual model presented in this paper, special attention was given to how, casting angles, curvature radii, etc. related to the mould development as well as that of plastic products-plastic euro pallets.

Product concept was based on the modular principles, allowing for stacking related modules as well as those of different dimensions. The synthesis of all these characteristics in a single product concept, combined with the advanced design promotes the pallet presented here as a new generation plastic pallet.

The importance and applicability of pallets in the production and distribution processes fully justifies any advanced approach to developing pallets as products, rather than as a tool.

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**Note:** The responsible translator for English language is J. Bajkin, Faculty of Technical Science, Novi Sad, Serbia