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Sodoben tržno prilagodljiv razvoj in proizvodnja novih modulno grajenih pločevinastih izdelkov

Modern Market Adaptable Development and Manufacturing of New Modular Sheet Metal Parts

TOMAŽ PEPELNJAK - BORIS JURKOŠEK - KARL KUZMAN

Sodoben razvoj in proizvodnja novih izdelkov terjajo povezovanje in sodelovanje vseh razvojnih in proizvodnih služb podjetja. Nov izdelek, po katerem povprašujejo na trgu, oblikujeta oblikovalec in konstrukter s sodelovanjem tehnologa glede na načrtovano ceno izdelka. Skupaj optimirajo geometrijsko obliko izdelka glede na razpoložljive proizvodne tehnologije. Vključevanje zamisli krojenih prirezov pri postopkih preoblikovanja izdelka izboljšuje njegovo trdnost ob minimalni porabi materiala. Oblikovanje in konstrukcijo izdelka je treba izpeljati izključno v virtualnem okolju (CA-x), kar omogočijo ustrezna računalniška orodja. Izhod iz virtualnega okolja CA-x je datoteka z geometrijskimi in tehnološkimi podatki o izdelku. Ta datoteka se nato prenese v prototipno delavnico ali orodjarno.

Prototipna izdelava je podprta s sodobnimi koncepti in tehnologijami hitre izdelave prototipov in/ali orodij. Tako se prototipe ali ničto serijo izdela v najkrajšem mogočem času. Pri optimiranju preoblikovalnega procesa lahko s slojevito gradnjo orodij hitro izvedemo rekonstrukcijo ali popravilo orodja.

Dobra povezava med vsemi oddelki, ki sodelujejo pri zasnovi in razvoju izdelka, zbiranje in vrednotenje informacij o morebitnih napakah v katerikoli razvojni fazi (FMEA) ter njihovo odpravljanje pred testno serijo, skrajšuje čase uvajanja novega izdelka. Z minimiranjem napak pri razvoju se zmanjšujejo tudi stroški zaradi morebitnih napak na izdelku, ki bi se lahko pojavili v redni proizvodnji.

V članku je predstavljen model celovitega povezovanja razvoja, proizvodnje in trženja, ki se od doslej poznanih sistemov razlikuje predvsem po povratnih informacijskih zankah. Z njimi se lahko odzivamo na hitre tržne spremembe in jim prilagajamo izbiro razvojnih in proizvodnih tehnologij za uvajanje in izdelavo novega ali obnovo sedanjega izdelka. Raziskave so potrdile ustreznost modela povezovanja vseh faz razvojnega sistema. Smeri razvoja novih izdelkov se nagibajo k nadaljnjemu širšemu povezovanju celotnega sistema razvoja s fazo proizvodnje in modernih metod trženja. Slednje omogočajo predvsem sodobni komunikacijski mediji, npr.: računalniški prodajni katalogi, internet in virtualne predstavitve izdelkov.

Ključne besede: preoblikovanje pločevine, gradnja modulna, metoda FMEA, trženje izdelkov

Modern integrated systems for the development and manufacturing of new products require cooperation between all services involved in this process. The design of new products to meet the market demands has to be performed according to its expected price through cooperation between the designer and the production engineer in order to achieve optimum part geometry according to available manufacturing technologies. To achieve optimum strength with minimum material use, the introduction of tailored blanks into the production process is recommended. Therefore, the concept and design of the product have to be prepared entirety in a virtual environment (CA-x), and this is made possible through powerful computer tools. The output of the virtual CA-x environment is a data file containing the geometrical and technological information about the new part. This file has to be transferred to the prototyping workshop or tooling plant.

The prototyping workshop is supported by modern concepts and technologies of rapid prototyping and/or tooling. This enables the manufacturing of prototypes and zero-series in the shortest possible time. In the case of forming process optimization, tool reconstruction is possible through a layered tooling concept. Good cooperation between all the participants involved in the conceptual phase and development of a new product, gathering information and evaluation of possible failures in all development phases (FMEA) and their elimination before the test-series helps to shorten development times. The cost minimization of possible product failures, which could appear in the production, is also significant.

The paper presents a model of integral linkage of development, manufacturing and marketing, which differs from the systems known to date, particularly since it includes feed-back information loops. These serve for responding to rapid market changes and adapting the selection process for developmental and manufacturing technologies in order to master and make new products or reconstruct the existing ones. The research work has shown that all development phases are successfully linked. Modern development concepts tend towards the further spreading of the global linkage of the development phases with manufacturing and current trade methods which are made possible through new communication media, such as computer sale catalogues, the internet and product presentation in virtual reality.

Keywords: sheet metal forming, modular concepts, FMEA method, product marketing

0 UVOD

Velika konkurenca v sodobni industrijski proizvodnji sili izdelovalce k nenehnemu skrajševanju časov razvoja in izdelave izdelka. Razvoj novega in obnovo sedanjega izdelka lahko skrajšujemo z uvajanjem novih računalniško podprtih tehnologij konstruiranja in načrtovanja proizvodnje. Pomembno vlogo ima tudi računalniško podprto optimiranje izdelka glede na njegovo napetostno-deformacijsko stanje, toplotne obremenitve itn. Vpeljevanje računalniške podpore v vse faze razvoja izdelka omogoča, da slednje prenašamo v virtualno okolje in prototipno serijo predstavljajo že optimirani izdelki. Čas izdelave prototipnih serij se je v zadnjih letih skrajšal (do 30%) z uvajanjem metod hitre izdelave prototipov [1] (laserska stereolitografija, selektivno lasersko sintranje itn.), s katerimi lahko izdelamo manjše serije prototipov brez uporabe običajnih orodij. V zadnjem letu se pojavljajo tudi že prve tehnologije izdelave kovinskih prototipov in orodij za tlačni liv, s katerimi hitro in natančno izdelamo ničto serijo z ustreznimi snovnimi lastnostmi.

Razvoj novih izdelkov v svetu se nagiba k opuščanju preverjanja novih izdelkov in orodij zanje z uporabo prototipnih serij [2]. V fazi testiranja so proizvodni sistemi, s katerimi virtualno preverimo in optimiramo izdelek in njegovo izdelavo do faze proizvodnje velikoserijskih orodij. Hkratna uporaba različnih računalniško podprtih (CA-x) programskih orodij je primerna v vseh omenjenih virtualnih razvojnih fazah - sočasno inženirstvo [3].

Za izboljšanje informacijske povezave med trženjem in razvojem izdelka, ki mora omogočati hiter odziv razvoja na tržna povpraševanja ob hkratni vrhunski kakovosti in sodobni proizvodnji novih izdelkov, je bil razvit model sistema globalne informacijske integracije. Namen omenjenega modela je skrajšanje razvojnih časov, zmanjšanje stroškov in zmožnost prilagajanja razvoja zahtevam trga.

1 SISTEM POVEZOVANJA RAZVOJA IN TRŽENJA MODULNO GRAJENIH IZDELKOV

V nekaterih industrijskih panogah je potrebna velikoserijska izdelava pločevinastih izdelkov, ki imajo velike ravne površine (nad 0,5 m^2) in se uporabljajo le kot okrovi aktivnih delov izdelka. Običajni načini izdelave uporabljajo izdelavo ene stranice okrova iz ene platine oziroma več stranic okrova iz ene platine in le redko omogočajo prilagodljivo izdelavo okrovov. Možnost izdelave različnih modelov v eni seriji, ki gre v velikosti nekaj 100 000 izdelkov na leto, je zelo majhna.

Pri iskanju novih rešitev povečevanja prilagodljivosti proizvodnje in tipizacije posameznih

0 INTRODUCTION

The enormous competition in modern industrial production forces manufacturers into the continual shortening of production and development times. Development of new products and redesign of existing ones can be shortened with the introduction of new computer aided technologies in design, process planning and product optimization (according to its stress-strain condition, thermal loads etc.). With most of these development phases now being carried out in a virtual environment it is possible to produce an already optimized prototype series. The time needed to manufacture the prototype batch has been drastically reduced over the last years (up to 30%) using the rapid prototyping (RP) technologies [1] (laser stereolithography, selective laser sintering, etc.) which enable the production of small batches of prototypes without the use of conventional tools. Last year, the first RP technologies for metal prototype production and rapid tooling for processes such as injection molding have been presented to produce fast and accurate zero series with corresponding material properties.

Trends in world production development [2] tend towards omitting the checking of products and their tools with prototype series. Manufacturing systems are being tested which will enable the evaluation and optimization of the product and its manufacturing, up to the tooling for large batch jobs, in a completely virtual environment. The parallel use of different CA-x tools in these phases is also essential - concurrent engineering [3].

To improve the connection between marketing and development information - which assures a fast, high quality and modern production of new products - a model of global information integration has been developed. The purpose of this model is to shorten development times, decrease costs and adapt development to market demands.

1 THE SYSTEM FOR THE INTEGRATION OF DEVELOPMENT, MARKETING, AND MODULIZATION OF PRODUCTS

In some industrial sectors, the production of large batch series of relatively large flat surfaces (0.5 m^2 or more) made of sheet metal is required. These parts are often used only as casings for the active product parts. Using conventional manufacturing technology, often one part per casing side - or even one part for more than one casing - side is produced. This decreases the manufacturing adaptability and model variation when the annual production is of several 100 000 parts.

A concept of the modular part and/or product design for sheet metal part production in large series

komponent izdelka je bil zasnovan sistem modulne gradnje pločevinastih izdelkov za masovno proizvodnjo. Zamisel modulne gradnje omogoča izdelavo večjega števila po geometrijski obliki sorodnih izdelkov. Testni izdelek lahko označimo z naslednjimi lastnostmi:

- pločevinski deli so relativno velikih dimenzij z lokalno povečanimi obremenitvami, od katerih je odvisna debelina pločevine za posamezne dele,
- pločevinski deli so površinsko zaščiteni,
- prilagodljivost izdelave je omejena (velike serije, velika orodja),
- omejena je geometrijska prilagodljivost (različice geometrijske oblike so omejene na število modelov izdelka).

Veliki pločevinski deli s temi lastnostmi so ob običajnem načinu izdelave pogosto razmeroma predimenzionirani. Najbolj obremenjena cona posameznega dela določa njegovo debelino, kar je povezano s preveliko porabo materiala. Uporaba krojenih prirezov s kombinacijo različnih in/ali različno debelih materialov zmanjša porabo materiala ob hkratnem izboljšanju mehanskih lastnosti izdelka. Rekonstrukcija izdelka, sprememba modela ali posebne želje kupca po nestandardnih dimenzijah izdelka pomenijo pri sedanjem načinu izdelave iz enovite debeline pločevine velike konstrukcijske zahteve in visoke investicijske stroške za nova orodja. Pomanjkljivost velikih orodij, ki so bila izdelana za določene različice izdelka v času konstrukcije in izdelave orodja, je majhna zmožnost prilagajanja tržnim spremembam. Prilagodljivost izdelave posameznih delov izdelka je minimalna, saj lahko z enim orodjem izdelujemo le en izdelek. V primeru sprememb v proizvodnji pred dokončno amortizacijo orodij ni mogoče porabiti delov orodja za proizvodnjo sorodnih izdelkov, kar je izvedljivo v primeru modulno grajenih izdelkov in orodij. Nova kombinacija modulno sestavljenih delov orodja omogoča njihovo uporabo za proizvodnjo po geometrijski obliki sorodnih izdelkov, kar izboljša amortizacijo orodja in poveča donosnost naložbe.

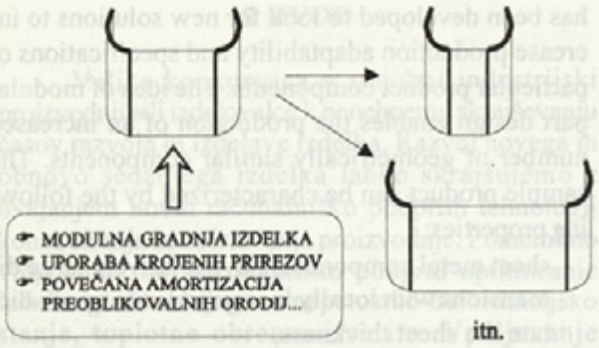
Z ustrezno konstrukcijo sedanjega izdelka lahko tega razdelimo na posamezne komponente (sl. 1). Z različnimi kombinacijami komponent se lahko poveča število sorodnih izdelkov. Za doseganje velike kakovosti izdelkov (dober videz, vodotesnost, geometrijska natančnost) moramo uporabiti sodobne tehnologije spajanja, npr.: lasersko varjenje, uporovno varjenje z gnetenjem in lepljenje. Z ustrezno modularnostjo komponent lahko izdelujemo izdelek glede na posebne zahteve kupca, pri čemer so določene komponente izdelane po meri. Prilagajanje dimenzijskim zahtevam povpraševanja lahko izvajamo s prilagodljivimi rezalnimi sistemi (npr. lasersko rezanje).

has been developed to look for new solutions to increase production adaptability and specifications of particular product components. The idea of modular part design enables the production of an increased number of geometrically similar components. The sample product can be characterized by the following properties:

- sheet metal components have relatively large dimensions with locally increased loads which dictate the sheet thickness,
- sheet metal components are surface coated,
- production flexibility is limited (large series, large tools),
- geometrical adaptability is limited (geometrical variants are limited to the number of models).

Conventionally produced sheet metal components are relatively oversized. The most loaded section determines the sheet thickness, which demands high material consumption according to modern design concepts. The use of tailored blanks with different materials and/or sheet thicknesses in one blank decreases this consumption with a parallel improvement in the part's mechanical properties. Product redesign, change of product variants or special customer demands (for non-standardized product sizes) require, in existing part production (using equal sheet thickness), enormous design efforts and high investment costs for new tools. The drawback of large tools, which determine product variants defined at the time of their production is their low adaptability to changing market demands. In the event of production changes before the amortization period of such tools, it is not possible to use their parts for the production of similar parts, which is when the product is designed in a modular way. The recombination of modular tooling parts enables the production of new products and leads to improved tooling amortization and return on investment.

Using appropriate design, an existing product can be divided into components (Fig. 1). This redesign increases the number of geometrically similar products with the use of different combinations of particular components. Modern joining technologies, such as laser welding, mash seam welding and adhesive joining, should be used to satisfy high quality requirements (such as visual, waterproof, high geometrical accuracy). With suitable component modularity it is possible to manufacture the product to a customer's particular request, where some components need to be produced according to special specifications. Adaptation to specified dimensions can be achieved by flexible cutting systems (e.g. laser cutting).



Sl. 1. *Modularno konstruiran izdelek*

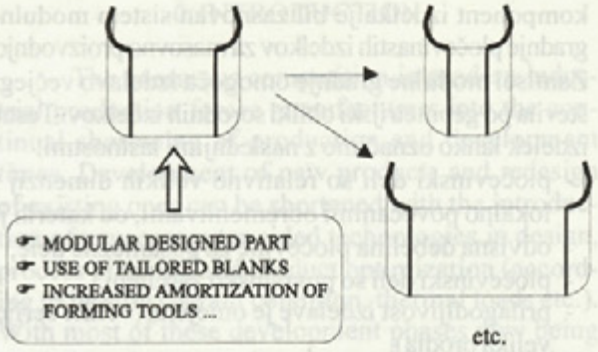


Fig. 1. *Modular designed product*

Brez natančnih informacij o odzivih trga na sedanje izdelke (variante modela) ne moremo vrednotiti možnosti njihove rekonstrukcije. V ta namen je nujno potrebna obojestranska informacijska povezava med službami trženja, razvoja in proizvodnje izdelka (sl. 2). Razvojna strategija vsakega podjetja naj bi temeljila na močnih informacijskih povezavah med vsemi službami, ki vplivajo na izdelek. Za izboljšanje povezav in sodelave med vsemi službami podjetja je bil razvit model strategije povezovanja, ki zajema sodobne razvojne, marketinške ter proizvodne koncepte in tehnologije (sl. 3). V tem sistemu imajo pomembno vlogo komunikacijske tehnologije, s katerimi najhitreje vzpostavljamo obojestranske povezave med potrebami trga, izbiro ustrezne razvojne tehnologije in optimalno proizvodnjo izdelka.

Sl. 2. *Informacijske povezave o izdelku*

Model integracije vseh služb podjetja, ki vplivajo na izdelek, je bil zasnovan za modularno gradnjo izdelka, s katero povečujemo prilagodljivost izdelave. Glede na vse večje zahteve po recikliranju in ponovni uporabi posameznih delov izdelka je bila v model integracije vključena tudi povratna zanka recikliranja izdelkov. Ta prenaša informacije o izrabljenih izdelkih do razvojnih oddelkov podjetja.

Informacijske povezave med trženjem, razvojem in prodajo terjajo sodobne računalniško podprte tehnologije v podjetju ter tesne povezave s prodajno mrežo. Sočasna izmenjava informacij med vsemi službami (od zasnove novega izdelka do njegove prodaje) je izvedljiva le z razvejanimi računalniškimi

Without precise information about the market response to existing product variants (model variants), it is not possible to estimate the potential for redesign. Therefore a two-way information flow between the market, development and production is necessary (Fig. 2). Each development strategy of an industrial enterprise should be based on strong information links between all product-affected services. To improve the links and cooperation of all these services, a strategy model has been developed which incorporates modern development, marketing and production concepts and technologies, including as well as communication technologies (Fig. 3). The shortest bidirectional link between the market demands, choice of appropriate development technology and optimum product manufacturing has still to be found.

Fig. 2. *Product information flow*

The model of integration of all product-affected services has been developed according to the modular concept, which enables additional flexibility in product manufacturing. According to strong demands on part recycling and re-use of some product components, a fedback used products recycling link has been incorporated into the development strategy model.

The information flow between marketing, development, and sales demands modern computer aided technology in enterprises and a strong connection with the marketing network. Only with good computer networking can the concurrent information exchange between all phases (from new product conception

mrežnimi povezavami. Prvi pogoj za vzpostavitev sistema je zadovoljiva računalniška pismenost vseh sodelujočih. Brez slednje niso mogoči ne vnos, ne vrednotenje in ne izmenjava podatkov o sedanjih in/ali novih izdelkih v vseh razvojnih, proizvodnih in tržnih službah.

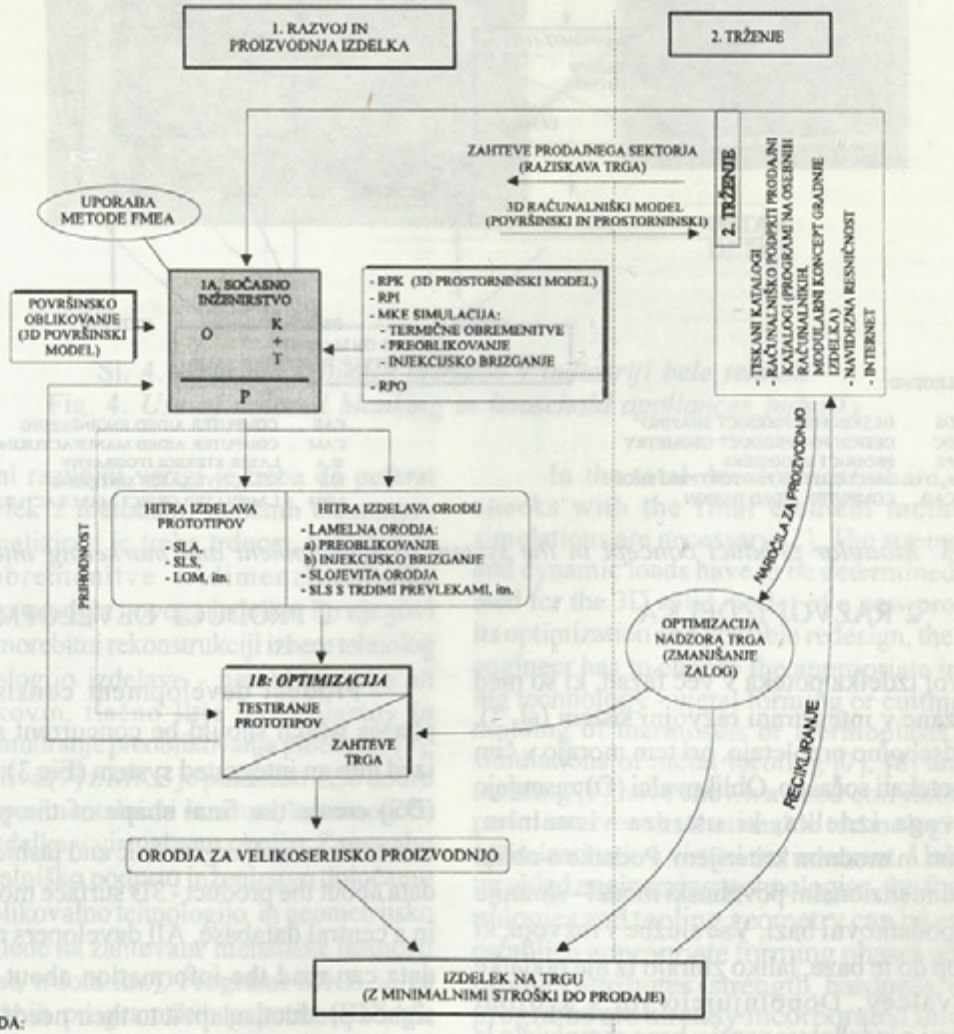
Za zagotovitev oblikovno, konstrukcijsko in tehnološko optimiranega izdelka, ki mora biti prodan kupcu v čim krajšem mogočem času in ob čim manjših proizvodnih stroških, je treba definirati povezave med razvojem, proizvodnjo in trženjem. S slike 3 so razvidne najpomembnejše povezave:

- trženje → razvoj: zahteve trga,
- trženje → razvoj: informacije o recikliranih delih,
- trženje → proizvodnja: optimizacija nadzora trga (zmanjšanje zalog),
- razvoj → trženje: 3D računalniški model izdelka,
- razvoj → proizvodnja: tržno usmerjena in optimirana proizvodna tehnologija.

up to the point of sale) be assured. A sufficient level of computer literacy is necessary in all phases involved, which is important for data input and evaluation of the existing and/or new products in all development, production and marketing services.

The primary links between development, production and marketing have to be in place to assure that the designed and technologically optimized product will reach the customer in the shortest possible time with the lowest development and production costs. Figure 3 shows the most important links:

- marketing → development: market demands,
- marketing → development : information about recycled parts,
- marketing → production: optimization of market control (decreased stocks),
- development → marketing: 3D computer model of a product,
- development → production: market oriented and optimized manufacturing technology.



Sl. 3. *Sistem razvojno-tržne integracije za modularno grajene izdelke*

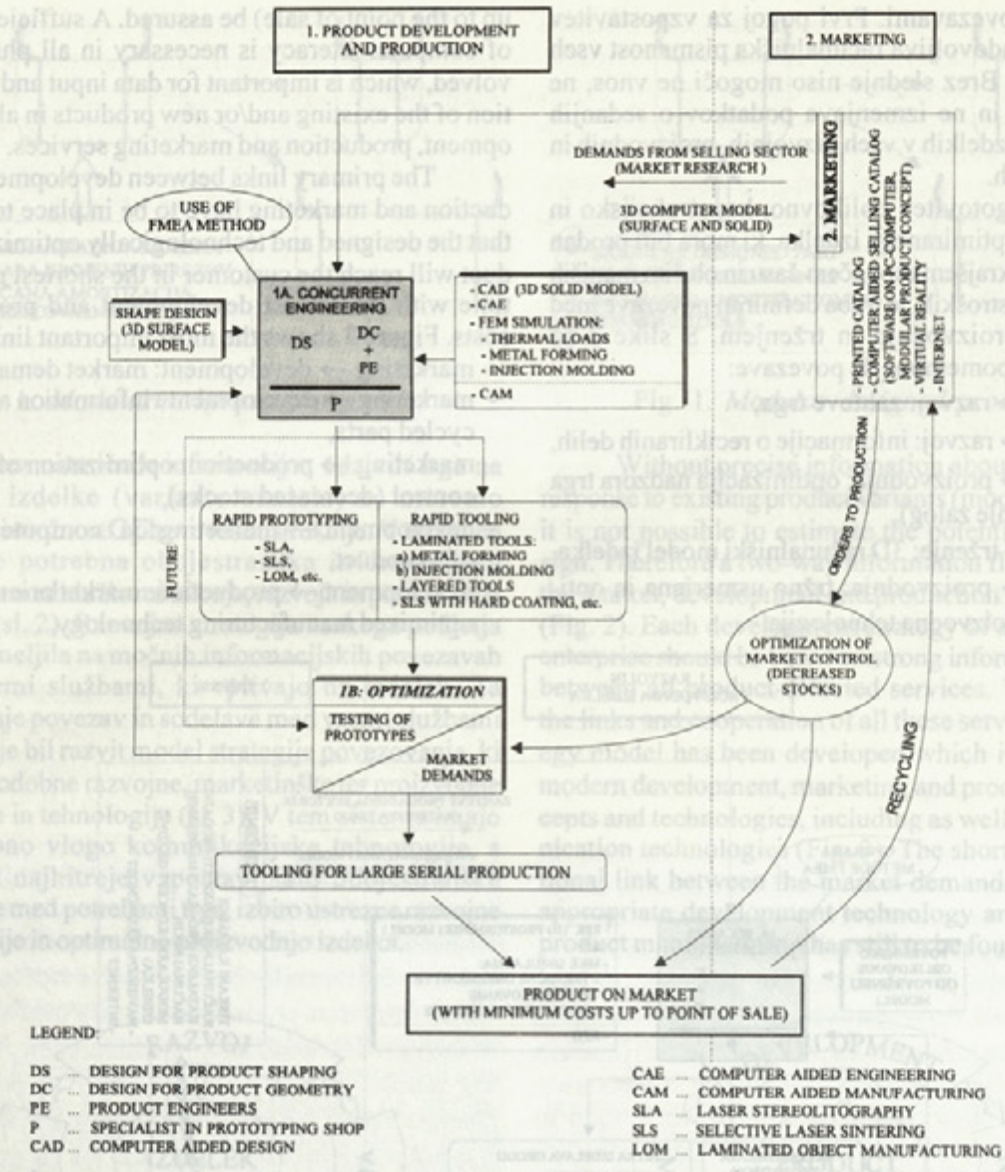


Fig. 3. *Modular product concept in the system of development and marketing integration*

2 RAZVOJ IZDELKA

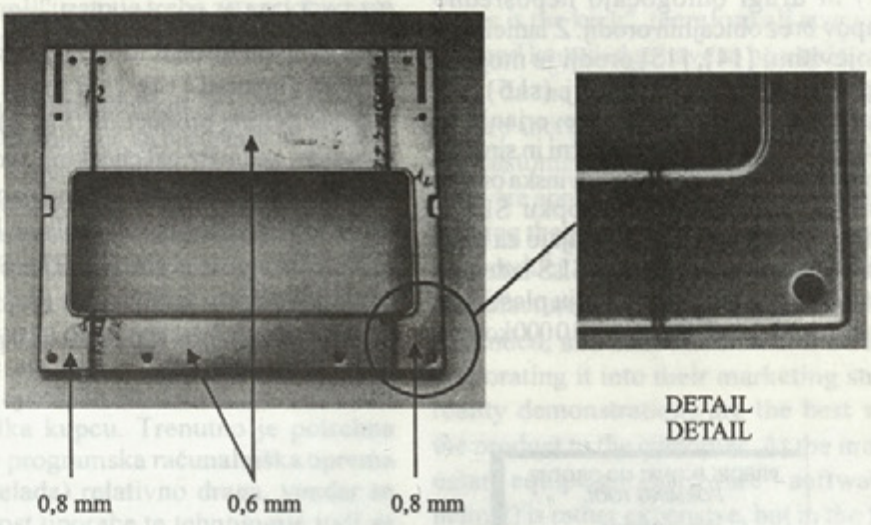
Razvoj izdelka poteka v več fazah, ki so med seboj povezane v integrirani razvojni sistem (sl. 3). Faze se medsebojno prepletajo, pri tem morajo v čim večji meri potekati sočasno. Oblikovalci (O) zasnujejo obliko novega izdelka, ki ustreza vizualnim, ergonomskim in modnim kriterijem. Podatke o obliki izdelka - tridimenzionalni površinski model - shranijo v centralni podatkovni bazi. Vse službe v razvoju, ki imajo dostop do te baze, lahko zbirajo iz nje podatke od oblikovalcev. Dopolnjujejo jih s svojimi informacijami o izdelku ter nazaj v bazo shranjujejo le dodane informacije o izdelku. Strogo določene pravice shranjevanja v podatkovno bazo onemogočajo podvojitev podatkov in minimirajo obseg podatkov o izdelku.

2 PRODUCT DEVELOPMENT

Product development consists of several phases which should be concurrent and are organized into an integrated system (Fig 3). The designers (DS) create the final shape of the product, which meets the visual, ergonomic and fashion criteria. The data about the product - 3D surface model - are stored in a central database. All developers requiring these data can read the information about the newly designed product, adapt it to their needs and store only additional data back to the database. The strictly defined storage rights of particular product information eliminate the possibility of its duplication and decrease the total amount of product data.

V naslednji razvojni fazi konstrukterji tridimenzionalni površinski model izdelka dopolnijo z debelino materiala, ojačitvami, spojnimi elementi itn. in pripravijo tridimenzionalni prostorninski model izdelka. Za minimiranje števila neustreznih razvojnih modelov izdelka je nujno sodelovanje konstrukterjev (K) in tehnologov (T), ki definirajo proizvodne tehnologije izdelka in njegovih posameznih komponent. Pri tem je nujno potrebno vključevanje metode analize mogočih napak in njihovih posledic. Uporaba sodobnih zasnov preoblikovanja pločevine, kakršna je npr. uporaba krojenih prirezov [4] do [6], ima pomembno vlogo pri sodelovanju konstrukterja in tehnologa (sl. 4).

Another design phase is necessary to build up a 3D surface model with data on material thickness, reinforcements, joining elements etc. and to generate a 3D solid model. Coordination between designer (DC) and production engineer (PE), who define the manufacturing technologies of the product and its components, is necessary to decrease the number of inappropriate product variants, and the use of a failure mode and effect analysis (FMEA) is essential in this process. The use of modern sheet metal forming concepts, such as the use of tailored blanks [4] to [6], plays an important role in the coordination of work between the designers and engineers (Fig. 4).



Sl. 4. *Uporaba krojenih prirezov v industriji bele tehnike*
Fig. 4. *Use of tailored blanking in household appliances industry*

V celotni razvojni verigi je treba do petkrat preverjati izdelek z metodami končnih elementov (MKE) [2]. Analizirati je treba trdnost, toplotne in dinamične obremenitve tridimenzionalnega prostorninskega modela novega izdelka. Po njegovi optimizaciji in morebitni rekonstrukciji izbere tehnolog ustrezno tehnologijo izdelave - preoblikovanje ali odrezovanje kovin, tlačno litje termoplastov in duroplastov. Simuliranje preoblikovanja pločevine [7], [8] in tlačnega liva [9] z MKE je pokazalo zelo dobro povezavo z eksperimentalnimi rezultati, kar omogoča optimizacijo izdelka v virtualnem okolju. Z uporabo orodij za računalniško podprto inženirstvo določamo ustrezno preoblikovalno tehnologijo in geometrijsko obliko orodij glede na zahtevane mehanske lastnosti izdelka (trdnost, trdota itn.). Programi MKE so že vključeni v tržnih programskih paketih (IDEAS, ProEngineer itn.). V razvoju so tudi večpredstavni (multimedijski) računalniški programi (integrirani rasterski, vektorski, tekstovni, vidni in slišni podatki), ki dajejo programom RPK/RPO nove razsežnosti uporabe [10].

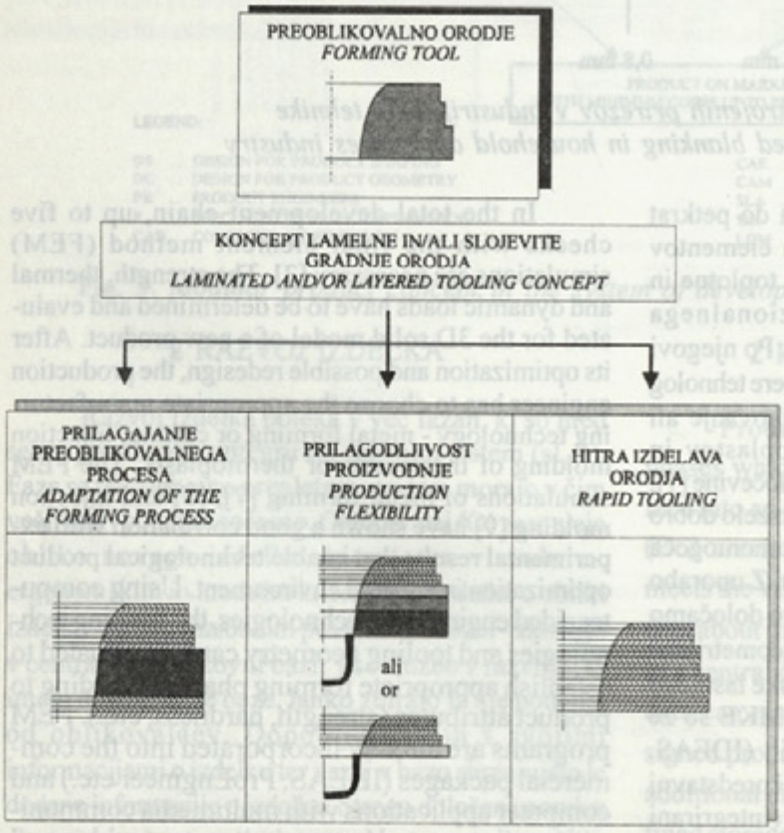
In the total development chain, up to five checks with the final element method (FEM) simulations are necessary [2]. The strength, thermal and dynamic loads have to be determined and evaluated for the 3D solid model of a new product. After its optimization and possible redesign, the production engineer has to choose the appropriate manufacturing technology - metal forming or cutting, injection molding of thermosets or thermoplasts. The FEM simulations of metal forming [7], [8] and injection molding [9] have shown a good correlation with experimental results that enable technological product optimization in a virtual environment. Using computer aided engineering technologies, the forming technologies and tooling geometry can be evaluated to establish appropriate forming phases according to product attributes (strength, hardness, etc.). FEM programs are already incorporated into the commercial packages (IDEAS, ProEngineer etc.) and computer applications with multimedia communications (integrated raster, vector, text, video and audio data) are in development to give the CAD/CAM programs new potentials [10].

S prototipno fazo je treba preveriti ustreznost konstrukcijske in tehnološke optimizacije izdelka in orodij za njegovo izdelavo. V bližnji prihodnosti se s skokovitim povečevanjem računalniških zmogljivosti in izboljšavami programov MKE ter njihovih modelov obeta celo opuščanje preverjanja RPI optimiranega izdelka s prototipi [2]. Slednji bodo v uporabi le za hitro proizvodnjo manjših serij - npr. za predstavitve na sejmih.

Izdelava prototipov in prototipnih orodij v prototipnih delavnicah (P) v zadnjih letih vedno bolj temelji na tehnologijah hitre izdelave prototipov (HIP-RP) in hitre izdelave orodij (HIO-RT) [11]. Postopki laserske stereolitografije (LS), selektivnega laserskega sintranja (SLS), slojevite gradnje objekta (SGO-LOM™) in drugi omogočajo neposredno izdelavo prototipov brez običajnih orodij. Z lamelnimi [12], [13] in slojevitimi [14], [15] orodji je mogoča hitra in prilagodljiva izdelava orodij (sl.5). Za vizualizacijo izdelka, geometrijsko preverjanje in izdelavo form za litje se uporabljajo plastični in sintrani materiali ter papir. Lamelna in slojevita kovinska orodja ali sintrana orodja, izdelana po postopku SLS z nanesenimi trdimi prevlekami se uporabljajo za hitro izdelavo orodij. Pri tem se po postopku SLS izdelana orodja največ uporabljajo pri tlačnem litju plastičnih materialov majhnih in srednje velikih serij (do 10 000 kosov).

It is necessary to verify the final design and technological optimization of the product and its tools in the prototyping phase. In the near future, the enormous increase of computer capacities and improvement of FEM programs and their models will make it possible to omit verification of the CAE optimized product by prototyping [2]. Prototypes will only be used for the fast production of small batch jobs - e.g. for presentations at trade fairs.

The production of prototypes and prototype tools in the prototyping shops (P) has recently been based on RP and rapid tooling (RT) technologies [11]. Laser stereolithography, selective laser sintering (SLS), LOM™ etc. enable direct prototyping without the conventional tools, whereas laminated [12], [13] and layered [14], [15] tools allow for fast and flexible tooling production (Fig. 5). For product visualization, geometrical checking and forming models - plastics, sintered materials and paper are used. Laminated and layered metal tools or hard metal coated SLS tools are used for RT. The SLS tools are used more efficiently in injection molding for small and medium batch jobs (up to 10 000 parts).



SLOJEVITO ORODJE ZA GLOBOKI VLEK [12]
LAYERED DEEP DRAWING TOOL [12]

Sl. 5. *Lamelna in slojevita orodja*
Fig. 5. *Laminated and layered tools*

V celotnem razvojnem sektorju je primerna vpeljava metode analize mogočih napak in njihovih posledic (FMEA). Z njo vrednotimo pojav napak in okvar ter njihov vpliv na razvoj izdelka v vseh razvojnih fazah. Pravočasno ugotavljanje okvar in učinkovita minimizacija napak skrajšuje čase ter zmanjšuje stroške razvoja novega izdelka.

3 TRŽENJE

Trženje izdelka ima zaradi svojega neposrednega stika z uporabnikom pomembno vlogo v podjetju. Pri kakovostnem trgovanju še vedno velja načelo "kupec je kralj", zato je treba za pridobivanje kupcev uporabiti vse razpoložljivo znanje in tehnologije.

V modernih tržnih oddelkih se povečuje uporaba računalniške tehnologije za predstavitev izdelka kupcu. Običajne tiskane kataloge dopolnjujejo računalniški programi na osebnih računalnikih. Z njimi se izboljšuje predstavitev izdelkov, omogočen je hitrejši pregled različnih različic izdelka ter komunikacija z izdelovalcem. Vse bolj se uporabljajo multimedijske predstavitve in nekateri izdelovalci jih že vključujejo v svoje prodajne strategije. Uporaba navidezne resničnosti je najboljša možnost za celovito predstavitev izdelka kupcu. Trenutno je potrebna oprema (strojna in programska računalniška oprema ter projekcijska čelada) relativno draga, vendar se napoveduje možnost uporabe te tehnologije tudi za potrebe trženja. S povečano zmožnostjo prilagajanja zahtevam trga lahko zadostimo potrebam večjega števila kupcev kakor nekoč ter zmanjšamo dobavne čase.

Mreža internet je najnovejši medij za odpiranje novih trgov. Je medij, ki dnevno omogoča nekaj deset milijonom potencialnih kupcev, da kupujejo s kreditno kartico ali navideznim denarjem. Informacijska omrežja kot je IndustryNet [16] in specializirani programi omogočajo uporabnikom precizno iskanje informacij o proizvodih in storitvah. Vse, kar mora podjetje pripraviti za trženje svojih izdelkov, je postavitev domače strani z vsemi potrebnimi informacijami o izdelkih in njihovih različicah ter posredovati prispela povpraševanja tržnemu sektorju podjetja. Pomemben vidik takega načina trženja izdelkov je zmanjšanje stroškov običajne prodajne mreže. Z neposredno povezavo izdelovalca in kupca se lahko zmanjšajo tudi stroški prevoza in zalog izdelkov.

S povezavo razvoja in trženja izdelka ter modularno gradnjo izdelka lahko izpeljemo konstrukcijske rešitve, s katerimi prepeljemo izdelek do kupca po delih ter ga šele pri njem sestavimo. Tipičen primer takšnega prevoza razstavljenih izdelkov najdemo pri pohištveni industriji.

In the whole development sector it is advisable to use failure mode and effect analysis (FMEA) to determine and evaluate the defects and their influence on product development in all development phases to immediately determine and minimize these failures in order to shorten the development time and decrease its cost.

3 MARKETING

Product marketing is an important part of an enterprise as it is the direct contact point with the customer. In quality trading it is stated that "the customer is the king", therefore all accessible technologies and knowledge have to be used to prove this true.

In the modern marketing department, computers are increasingly used to present the product to the customer. Printed catalogues are supported by software applications on personal computers, thus improving the presentation of the product, faster lookup for product variants and communications with the manufacturers. The use of multimedia is still being expanded, and some manufacturers are already incorporating it into their marketing strategy. Virtual reality demonstrations are the best way to present the product to the customer. At the moment, the necessary equipment (hardware + software + projection helmet) is rather expensive, but in the future it will be possible to use this equipment in the marketing sector. With the increased adaptability to market demands it is possible to satisfy more customers' requirements than before and to minimize the delivery times.

The internet is the newest medium used to increase trade. This medium daily enables ten million or more potential customers to buy by credit card or E-Cash (virtual cash). Information networks such as IndustryNet [16] and specialized search engines allow users to find out specific information. All you need to do to market your products is to set up your homepage, listing all product variants and to channel the incoming information into the marketing department of the company. An essential aspect of such a marketing method is that the costs of the current sales network can be reduced. The transport costs and stock levels can be decreased due to the direct link between the company and the customer.

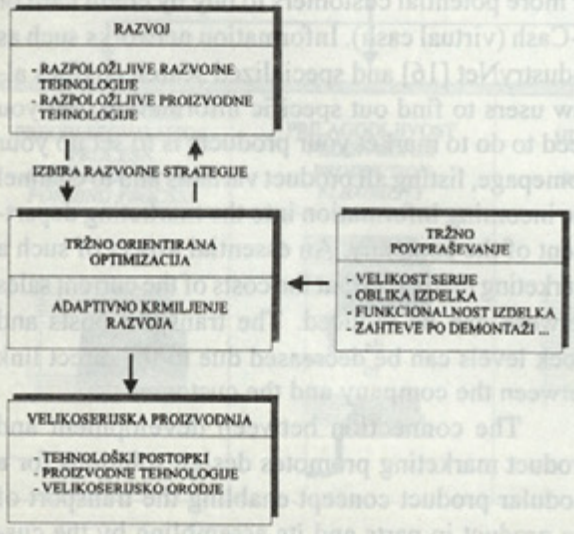
The connection between development and product marketing promotes design solutions for a modular product concept enabling the transport of the product in parts and its assembling by the customer - a typical case of such product transportation is found with the furniture industry.

Za zadostitev ekoloških zahtev, ki so v nekaterih državah že predpisane z zakonom, bo izdelovalec kmalu prisiljen vzeti izrabljene izdelke nazaj. V modelu razvojno tržne integracije je načrtovana povratna informacijska zveza o rabljenih izdelkih. Zahteve po preprostosti demontaže izdelka in informacije izdelovalca o ponovni uporabi njegovih posameznih delov morajo biti sporočene razvojnemu sektorju. Ta lahko s konstruiranjem ustrezne modularnosti izdelka skrajša čase njegove demontaže.

Z uporabo računalniško podprtih orodij (računalniški prodajni katalogi, internet) se lahko optimira in minimira potrebne zaloge izdelkov oz. delov izdelkov, kar je povezano z nižjimi prevoznimi in skladiščnimi stroški. Uporaba modernih informacijskih tehnologij v tržnem sektorju je upravičena, če omogoča skrajševanje dobavnih časov. Sprotno naročanje izdelkov terja tržno orientiran razvoj, definiranje načina izdelave prototipov, prototipnih serij in vseh drugih faz, ki so potrebne za zagon velikoserijske proizvodnje.

4 OPTIMIZACIJA

Optimizacija razvoja novega izdelka glede na zahteve trga je tisti segment predstavljenega modela razvojno-tržnih povezav, ki s sodobnimi informacijskimi tehnologijami ob integraciji računalniško podprtih tehnologij v razvoju hitro povezuje informacije s trga (npr. neposredna naročila izdelka ali zahteve po njegovih spremembah) z izbiro ustrezne razvojne strategije (sl. 6). Glede na poprej definirane odločitvene kriterije lahko izberemo optimalno proizvodno tehnologijo. Pri optimizaciji uporabljamo nevronske mreže ali genetske algoritme. S tem se zmanjša število potrebnih prototipov izdelkov ali orodij za preverjanje ustreznosti slednjih. Hkrati je treba izbirati ustrezno tehnologijo izdelave prototipov glede na velikost serije izdelkov. Pri majhnih serijah lahko končni izdelek izdelamo kar s prototipnimi orodji, če so ta dovolj natančno izdelana.



Sl. 6. *Tržno usmerjena optimizacija razvoja izdelka*

In order too fulfill all ecological requirements - which are in some countries defined by law, the manufacturer is forced to take the worn-out product back. In the model of development and selling integration, an inforamtion loop for used products has been incorporated. The simple disassembly of the product using the manufacturer's information about the possible re-use of particular used parts has to be passed on to the developers, in which appropriate product modularity can shorten the disassembly times.

Using computer aided technologies (computer selling catalogues, internet), it is possible to optimize and minimize necessary product and part stocks which are connected with smaller transportation and stocks costs. Use of modern information technology in the marketing sector is sensible, if it allows for the shortening of delivery times. On-line product ordering demands strong market-oriented development by prototyping definition, prototyping series and all other phases leading to the final large series production.

4 OPTIMIZATION

The development optimization of a new product according to market demands is the part of the presented model of developmental-market links which rapidly connects information from the market (e.g. direct orders for products or demands for their changes) with the selection of an appropriate developmental strategy through the use of modern information technologies and by integrating computer-aided technologies in the developmental process (Fig.6). According to the predefined criteria of a decision system, where neural networks or genetic algorithms have to be used, the optimum production technology will be chosen. Through these optimization procedures, the amount of prototypes necessary for product and tooling verification can be reduced by a simultaneous decision about prototyping technology according to the batch size. In the case of a small batch job, the final part can be manufactured with prototype tools - the assumption is that these tools are sufficiently accurate.

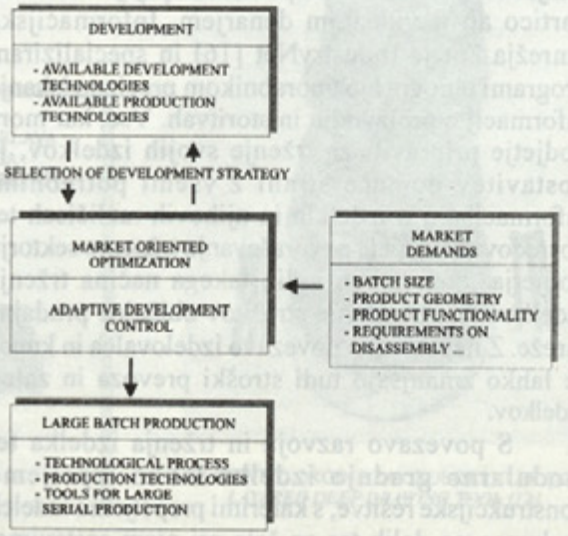


Fig. 6. *Market-oriented optimization of product development*

Baza znanja o spremembah sedanjih izdelkov, uspešna konstrukcija in izbira tehnologije imajo pomembno vlogo v razvojnem sektorju. Z njimi se izognemo neuspešnim rešitvam pri vrednotenju izdelka za določeno velikost serije. Takšna integracija "razvoja za trženje" skrajšuje razvojne čase in stroške. Nov ali delno spremenjen izdelek lahko zaradi tega hitreje doseže tržišče, kar povečuje prilagodljivost tržnim zahtevam.

Optimizacijo prototipne faze naj bi v prihodnosti izvajali v virtualnem okolju. V ta namen razvijamo in pripravljamo ustrezne sisteme za virtualno izdelavo in preverjanje prototipov.

5 SKLEPI

Predstavljeni model povezave razvoja in trženja, ki zagotavlja zmanjšanje stroškov in optimizacijo razvojnih časov, temelji na predpostavki o sodelavi in zadovoljivi računalniški pismenosti vseh služb v podjetju, ki so povezane v integracijski model. Modularna zasnova gradnje izdelka temelji na sodobni konstrukciji in proizvodnih tehnologijah ter pomeni pomemben segment v povečevanju prilagajanja proizvodnje na dinamične tržne zahteve. Za optimalno izpolnjevanje zahtev integracijskega modela moramo uporabljati sodobne tehnologije laserskega rezanja in varjenja, preoblikovanje krojenih prirezov, sodobna lepila, ki so odporna na visoke temperature, hitro izdelavo prototipov in tehnologije hitre izdelave orodij ter nove optimizacijske metode (genetski algoritmi). Model je odprtega tipa in ga lahko neprestano dopolnjujemo z novimi sodobnimi metodami in tehnologijami. Kombinacija modularne gradnje izdelka in sodobnih tehnologij, ki jih povezujemo z novimi informacijskimi tehnologijami, skrajšujejo dobavne čase, zmanjšujejo potrebne zaloge izdelkov ter izboljšujejo njihovo kakovost. Izboljšuje se tudi povezava med izdelovalcem in kupcem.

Z uporabo povratnih informacijskih zvez med razvojem, trženjem in proizvodnjo se postavlja nov model celovitega razvojno-proizvodnega krmiljenja, ki se lahko hitro odziva na nova tržna povpraševanja in zahteve, s čimer postavlja nadgradnjo dosedanjih sistemov sočasnega inženirstva in povezovanja med razvojem, trženjem in proizvodnjo.

In ne nazadnje je za globalno povezovanje razvoja, trženja in proizvodnje nujno potrebno intenzivno sodelovanje vseh delov modela. Vključevanje posameznih služb podjetja v potrebnem časovnem intervalu delovanja sistema glede na njihova znanja in izkušnje je nujno za uspešno delovanje integracijskega modela.

Kombinacija različnih računalniško podprtih tehnologij konstrukcije (RPK), inženirstva (RPI), priprave proizvodnega procesa (RPPP), hitre izdelave

The knowledge base about modifications of existing parts and success of the chosen design and technological variants has an important role in the development sector in eliminating unsuccessful solutions through product evaluation for particular batch size. Such "development for marketing" integration shorters development times and costs. The new or modified product can therefore appear more quickly on the market, with improved adaptability to market demands.

In the future, the optimization of the prototyping phase should be carried out in virtual reality; therefore, the appropriate systems for this new way of virtual prototyping have to be prepared.

5 CONCLUSIONS

The presented system of linking development and marketing - which ensures a reduction of costs and time optimization - is based on the expectation of cooperation and sufficient computer literacy in all services involved in the system. The modular product concept based on modern design and manufacturing technology is an important part of the increased adaptability to dynamic market demands. The laser cutting and welding, forming of tailored blanks and contemporary high temperature resistant adhesives, rapid prototyping and tooling technologies, new optimization methods (genetic algorithms) etc. have to be used to fulfill the optimum system requirements.The model is of the open type and can be constantly supplemented by new modern methods and technologies. The combination of modular part concepts and modern technologies, connected with new information technologies, will shorten the delivery times and decrease the stock requirements, with the consequent shortening of marketing links from the producer to the customer.

Using information feedback between the phases of development, marketing and manufacturing, a new model of overall development-manufacturing control has been set-up which will be able to rapidly respond to new market demands and requirements. This makes it an upgrading from the previous systems of concurrent engineering and the linkage between development, marketing and manufacturing.

Last, but not least, intense cooperation between all model segments is essential for an overall integration of development, marketing and manufacturing. The participation of professionally experienced individual services in the company during a certain time interval of system operation is essential for the successful functioning of the integration model.

The combination of different computer - aided tools for product design (CAD), engineering (CAE), proces planning (CAPP), rapid protoyping (CARP),

prototipov (RPHIP), obdelave (RPO) in zagotavljanja kvalitete (RPZK) ter večanje zmogljivosti računalnikov, sodobne proizvodne tehnologije in komunikacije dajejo predstavljenemu modelu povezovanja razvoja in trženja možnost, da postane v bližnji prihodnosti industrijska realnost.

manufacturing (CAM), quality control (CAQ), and increased computer capacities, modern manufacturing technologies and communications enable the presented model of coordinated development and marketing to become an industrial reality in the near future.

6 LITERATURA
6 REFERENCES

[1] Jacobs, P.F.: Stereolitography and other RP&M technologies. ASME Press 1996.

[2] Makinouchi, A.: Sheet metal forming simulation in industry. J. Mat. Proc. Tech. 60,1996, 19-26.

[3] Young, A.R., N. Allen: Concurrent engineering and product specification. J. Mat. Proc.Tech. 61,1996, 181-186.

[4] Irving, B.: Welding tailored blanks is hot issue for automakers. Welding Journal, Vol. 74,1995/8, 47-50.

[5] Vollertsen, F.: Tailored blanks. Blech Rohre Profile, 42,1995/3, 172-178.

[6] Pepelnjak, T, B. Jurkošek, K. Kuzman, B. Jeseničnik: Research on the forming of tailored blanks in conventional tools. Proc. of 30th Int. CIRP Seminar on Manuf. Systems - LANE '97, Hrsg./Ed.: M. Geiger, F. Vollertsen, Meisenbach Verlag, Bamberg 1997, 767-778.

[7] Kampuš, Z., K. Kuzman: Experimental and numerical (FEM) analysis of deep drawing of relatively thick sheet metal. J. Mat. Proc. Tech. 34,1992, 133-140.

[8] El Khaldi, F., Lefebvre, D., Mehrez, et al: Sheet metal forming: state-of-the-art of the application methodology and simulation streamlining. Proc. of 19th IDDRG Biennial Congress, Hungary 1996, 199-214.

[9] Nardin, B., K. Kuzman, F. Kadiš: Practical application of CAE in supporting the development of new product. Proc. of. ICIT'97, Maribor 1997, 325-328.

[10] Puttre, M.: Multimedia technology opens windows on engineering tasks. Mechanical Engineering. April, 1993, str.p. 67.

[11] Wohlers Associates, Industry Watch: Rapid prototyping growth continues. Rapid Prototyping Report, Vol. 4 , 1994/6, 6-8.

[12] Kuzman, K., T. Pepelnjak, P. Hoffmann, Z. Kampuš, V. Rogelj: Laser cut sheets - one of the basic elements for low cost tooling system in sheet metal forming. Manufacturing Systems, Vol. 24,1995/6, 563-569.

[13] Hoffmann, P., H. W. Bergmann: Lasergestütztes Rapid Tooling, Proc. of 12th Int. Congress LASER'95, Hrsg./Ed.: M. Geiger, Meisenbach Verlag, Bamberg 1995, 135-149.

[14] Pepelnjak, T., Z. Kampuš, K. Kuzman: Layered tool structure for improved flexibility of metal forming processes. Advanced Manufacturing Systems and Technology , CISM Courses and Lectures No. 372 , ISBN 3-211-82808-7, Springer - Verlag , Wien, New York 1996, 339-346.

[15] Pepelnjak, T., K. Kuzman: Raziskave fleksibilnih orodnih sklopov za preoblikovanje pločevine. Magistrsko delo, Univerza v Ljubljani, Fakulteta za strojništvo, Ljubljana 1996.

[16] Internet: http://www.industry.net

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