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RFID tehnologija u službi fleksibilnog programiranja CNC mašina

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U članku se iznose novi pogledi na parametarsko programiranje CNC mašina. RFID tehnologija može pružiti dobru osnovu kao nosilac tehnoloških i geometrijskih informacija naročito ako je mašina uključena u fleksibilnu proizvodnju delova manjeg gabarita i velike učestalosti pojavljivanja. Parametarsko programiranje ovog tipa može biti jedna od karika koja vodi ka adaptivnom upravljanju u realnom vremenu.

Ključne reči: RFID – radio frekventna identifikacija, Parametrisjko programiranje, CAD/CAM, DNC

1. UVOD

Konstruktivni zahtevi proizvodnih delova nametnuli su razvoj novijih upravljačkih jedinica, kako elemenata hardvera tako i softvera. U ovom radu akcenat će biti usmeren samo na onaj deo softvera upravljačkih jedinica koji se odnosi na parametarsko programiranje. Terminološki posmatrano pod pojmom parametarskog programiranja, u zavisnosti od proizvođača upravljačih jedinica, sreću se sinonimi: makro programiranje i fleksibilno programiranje. Istorijski posmatrano proizvođači upravljačkih sistema, u početnoj fazi razvoja, nisu imali nameru da korisniku daju mogućnost parametarskog programiranja. Međutim, sama potreba nametnuta razvojem složenijih konstruktivnih rešenja CNC mašina, složenost obradaka, težnja ka bržem programiranju, naročito u tipskim/grupnim tehnologijama, neminovno je nametnula implementaciju ove vrste programiranja u softverska rešenja upravljačkih jedinica. Parametarsko programiranje nije unificirano i zavisi od proizvođača upravljačke jedinice, te je analiza pokazala i neznatno odstupanje unutar jedne vrste upravljačkih jedinica. Proučavanjem literature [5] i [6], došlo se do činenice da više različitih upravljačikih jedinica drugih proizvođača imaju isti način (tip) parametarskog programiranja, dok su drugi prozvoćači upravljačkih sistema razvili poseban jezik relevantan za parmetarsko programiranje.

Dobro poznavanje programiranja u G kodu je prvi preduslov za uspešno parametarsko programiranje. Prema [4], za složenija parametarska programiranja neophodno je, dodatno, poznavanje programiranja računara na nižem programskom nivou, kao i poznavanje procesa (obrade i upravljanje komponentama mašine).

U ovom kraktkom pregledu razvoja i impementacije parametarskog programiranja, treba istaći da sa današnjeg stepena programiranja ovo programiranje vraća korisnika na nivo programiranja programskih jezika nekoliko godina unazad (tip BASIC). Korisnost parametarskog programiranja donosi, nesumljivo, prednosti koje se ogledaju u brzini rada napisanog programa, manjem zauzeću programske memorije što je posledica kraćeg programa u odnosu na tipski [3].

Razvoj RFID tehnologije otvorio je mogućnost drugačijeg pristupa za ovu vrstu programiranja CNC mašina. Očekivani rezultati na polju parametarskog (MACRO ili fleksibilnog) programiranja u saradnji sa RFID tehnologijom mogu dati benefite u cilju povećanja: fleksibilnosti tehnološkog postupka, optimizaciji i unapređenju procesa, kreiranju CNC programa u fazi identifikacije obradaka i mogućnosti izmene tehnološkog postupka u fazi procesa obrade (u slučajevima fleksibilne proizvodnje). Doprinosi ovakvog pristupa projektovanju obradnog procesa su naročito efikasni i fleksibilni.

Primarni cilj rada je istraživanje, razvoj projektovanja procesa obrade primenom MACRO ili fleksibilnog programiranja u sadejstvu sa RFID tehnologijom. Pored navedenog sekundarni cilj rada je iznalaženje brzih, upravljanju nepoznatih, ad hok, nepredvidivih rešenja u procesu projektovanja koja sama po sebi proces približavaju adaptivnom.

Iz predhodno izloženog, na dalje, u narednim poglavljima, prezentiraju se pravci istraživanja i analiza parametarskog programiranja u relevantnoj literaturi i ukratko se daju osnove RFID tehnologije, metodologije i rezultati istrživanja.

2. PREGLED LITERATURE

Prema analizi sprovedenoj na korisničkoj literaturi kao i u preporukama više proizvođača upraljačkih jedinica, parametarsko programiranje je najviše korišćeno za:

- programiranje familije delova,
- definisanje specifičnih ciklusa,
- specifične konstruktivane fičere konstrukcija koji se ponavljaju,
- složena programska kretanja, kao što su parabole, elipse itd.,
- specifičnu instaliranu dodatnu opremu (npr. oprema za merenje),
- “Smart” programe, i
- makro programe koji mogu donositi odluke pomoću uslovnih iskaza.

Shodno nabrojanom ukratko se daju specifičnosti izdvojenih naučnih radova.

Jedan od prvih radova koji razmatraju parametarsko proramiranje je rad „A Parametric Programming Technique

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For Efficient CNC Machining Operations" autora Manocher Djassemi [9]. Autor navodi definiciju parametarskog programiranja ističući da je: parametarsko programiranje je G / M kodno programiranje u kojoj je pozicije osa (x, i, z, a, itd.), funkcija posmaka i brzine mogu biti određeni parametarskim izrazom/ma i da je način programiranja sličan kompjuterskim programskim jezicima kao što su Pascal ili C, kod kojih se kompjuterske funkcije kao što su promenljive, aritmetiki, logički izrazi i programske petlje mogu programirati u parametarskom obliku. Takođe u radu se navodi primena parametarskog programiranja na osnovu grupisanja sličnosti dizajna i grupisanja na osnovu zahteva obrade. Autor uvodi pojmove vezane za tehnike paramatarskog programiranja kao što su:

- Feature-Base CNC Programming navodeći neke od modula parametarskog programa kao što su Hole, Pocket, Thread itd., i
- Repeated features čiji slučajevi parametarskog programiranja nalaze primenu u situacijama kod kojih se višestruko pojavljuju features različitih dimenzija.

Primena oba tipa programiranja ogleda se u kompoziciji modula u glavnom programu.

U samom radu, putem primera, prezentiraju se oba vida programiranja upoređujući paralelno, klasično CNC programiranje i parametarsko programiranje za oba navedena tipa, ističući, u samom zaključku, prednosti parametarskog programiranja koje se ogleda u: jednostavnijem i bržem programiranju kao i smanjenu dužine programa.

Tipovi promenljivih imaju važnu ulogu u prametarskom programiranju ističe u tekstu Variable in Custom Macro Mike Lunch [21]. Klasifikuje ih u pet tipova korisničkih Makro promenljivih; Letter address arguments, lokalne promenljive, zajedničke promenljive (vraćaju se u predašnje stanje po isključivanju mašine), stalne zajedničke varijable (čuvaju se i posle isključivanja mašine), i sistemske varijable koje se koriste za pristup relevantnim CNC funkcijama. Posebno izdvaja stabilne / nestabilne varijable, dajući savet budućim korisnicima na koji način bi trebali da koriste određene tipove ovih varijabli. Iznosi konstataciju da su lokalne promenljive nestabilne jer po isključivanju mašine gube svoju aktivnost, nasuprot stabilnim varijablama, koje autor preporučuje u slučajevima kad nestabilnost izaziva neki tip problema. Svoje konstatacije potkrepljuje primerima za oba slučaja. Primer primene lokalnih varijabli potkrepljuje tvrdnjom da posle realizacije glodanja (rezanja) svih navoja ove varijable više nisu potrebne. Nasuprot, ovome, stalne varijable mogu se koristi za više programa, npr. za one za koje važi ista brzina i posmak, te i posle isključivanja mašine ostaju aktivne. Ovakvim pristupom benefiti su očigledni u smanjenju broja varijabli. Pri upotrebi varijabli korisnici moraju imati određenu dozu opreznosti. Deo stalnih zajedničkih varijabli moraju ostati stalno prisutne, naročito u slučajevima kada su prisutni u upotrebi određeni pribori i uređaji za merenje (spindle touch probe).

Parametarsko programiranje sa stanovišta složenih nesimetričnih struktura sa posebnim akcentom na sračunavanje brzine izvršavanja programskih naredbi i brzine kretanja je predmet istraživanja autora Grzegorz Nikiel u radu [12]. S obzirom da se analiza sprovodi korišćenjem upravljačke jedinice Sinumerik 810D, to ne znači da nije metodolološki primenljiva i na druge tipove upravljačkih jedinica. Problematika analizirana tokom istrživanja sprovedena je na: sračunavanju brzine celobrojnih varijabli, realnih varijabli, proračunu kompleksnih funkcija na primeru kvadratnog funkcije (x^2), brzina kalkulacije za kompleksne aritmetičke izraze - u jednom bloku i u nekoliko blokova sa razgradnjom na jednostavnije brzine sračunavanja sa korišćenjem različitih strukturktura narebi - WHILE … ENDWHILE, REPEAT … UNTIL, FOR.. ENDFOR, IF…GOTOB/GOTOF i brzina proračuna sa upotrebom potprograma. Radi sveobuhvatnije analize i razumevanja, daju se i osnove parametarskog programiranja za ovaj tip upravljanja i promenljive koje se koriste za primer optimizacije sa uporednim paramerima. Zaključci izvedeni na osnovu izloženog upućuju na preporuke koje bi programeri koji primenjuju parametarsko programiranje trebali imati u vidu (ne samo za Sinumerik Control), u cilju bržeg izvođenja progama, a oni se odnose na:

- primenu operacija računanja sa parametrima (R-parametarima) za koje je brzina proračuna za različite varijable (integer, real) približana,
- izbegavanje primene uslovnih instrukcije skoka (IF... GOTOx) u korist drugih strukturnih uputstva (WHILE … DO, REPEAT … UNTIL itd), i
- izbegavanje primene potprograma, koja donosi određena usporenja pri izvršavanju programa

Kao rezultat eksperimentalnog merenja sračunavanja brzina operacija sa promenljivim izdvavaju se u vidu tabelarnih navoda kao rezultati istraživanja, koji sažeti se mogu objediniti u sledećem:

- brzina izvršavanja parametarskog programa primenom R parametara u odnosu na LUD,
- korišćenje heap i nekorišćenje heap, i
- neprimenjivanje podprograma u odnosu na podprograme,

dajući povećanu brzinu realizacije programa. Iz priloženog može se analizirati i zaključiti koji ključni elementi programa kao i način programiranja imaju dominantni uticaj na brzinu izvršavanja programa. Takođe navode se i dodatni elemenati koji mogu uticati na usporenje brzine izvršavanja dela programske strukture (npr. numeracija blokova, komentari itd.).

Posebno treba istaći radove koji se bave tematikom zasnovanom na specifičnostima same obrade: kako geometrijskom (prvenstveno radi tačnosti) tako i tehnološkom (specifičnosti grupnog i tipskog načini obrade). Iz tih razloga, na dalje daju se radovi koja potkrepljuju ovu konstataciju.

Rad Zhu Xiurongand i Zhang Guangcheng, u svom naučnom radu [10] pored naučnog doprinosa na polju tehnologije obrade na strugu tankozidnih elemenata, daju u uvodnom delu o prametarskom programiranju tabelu uporednih mogućnosti klasičnog i parametarskog programiranja (Tabela 1.), ističući u svojim navodima lakoću modifikacije i čitljivosti makro programa u odnosu na klasično, redosledno programiranje.

Tabela 1. Poređenje Macro i klasičnog (Ordinary manual) programiranja (preuzeto iz [10])

Ručno programiranje	Macro programiranje
Koriste se samo konstante	Koriste se promenljive i dodela vrednosti promenljivima
Nekoriste se operacije između konstanti	Moguće su operacije između varijabli
Program je obično redosledan, I nemože biti preskočiv	Program može biti preskočiv
Uobičajna vrsta programiranja	Macro programiranje

Krive linije imaju određenu pogodnost za primenu parametarskog programiranja u sledećim industrijama: automobilskoj i brodogradnji, zatim kod alata za istiskivanje, alata za rolo oblike, profile turbina i dr. a predstavljeni su u radu [13]. CAD softveri koriste parametarske krive formirjući ih u granicama gornjeg i donjeg odstupanja u cilju dobijanja adekvatnog oblika. Što su granice odstupanja manje to je i povećana tačnost izrade koju generiše CAM softver. Parametarsko programiranje mora posedovati jednačinu krive preko koje se upravlja geometrijom kroz smenu parametara. Kako se kroz navedeni rad za primer uzima i prezentira parametarsko programiranje Bezier profilnih krivih linija kao reprezenta ove grupacije krivih linija to je relevantna jednačina data u obliku:

Tabela 2. Rezultati uporedne analize proramiranja CAM tehnologije i parametarskog programiranja (preuzeto iz [13])

Pređenje Features		Kriva-								Luk-	
		C	Para met	C	Para met	C	Para met	C	Para met	CA	Para met
Broj rečenica/		20	53	12	41	14	41	18	41	17	41
Vreme		1	1M	1M	1M	1		1M	1M	1	1M
Tačnost	Mi	-	-	-	-	-	-	0	0.5	-	0.0
	M	0	0.9	0	0.5	0	0.8	0	0.7	0	0.9
	Pr	-	0.1	0	0.0	0	0.2	0	0.0	0	-
	R	0	0.2	0	0.2	0	0.1	0	0.2	0	0.3

Kod CAM tehnologije akcenat tačnosti je zasnovan na gornjem i donjem odstupanju od Bezier profila u čijim granicama su rasprostranjene interpolacione linije. Kada se Bezier kriva realizuje putem parametarskog programiranja tada parametar "u" (inkrement) zavisi od korisnika kao i parametara obrade. Sa povećanjem broja ovog parametra povećava se broj inkrementalnih linija, što direktno utiče na tačnost obrade. Autori rezultate obrade prikazuju putem tabela 2.

Autor u radu [20] na osnovu teorijskih postavki vezanih za nastale ugibe pod dejstvom komponente prodiranja (F_x), a uzimajući u obzir greške nastale: kao posledicu krutosti radnog predmeta, pomoćnog pribora za stezanje i sklopa radnog vretena, uvodi i prezentira teorijske postavke koje implementira u parametarsko programiranje čime se odklanjaju, tj. kompezuju greške obrade.

Kompletnu analizu sprovode za dvosne CNC mašine (CNC strugarske centre) dajući matematički model za dva geometrijska oblika ističući da su nastale greške obrade posledica: geometrijskih grešaka svojstvene alatnim mašinama, termički indukovanim distorzijama i statičkim ugibima na obradnom sistemu nastalim pod uticajem sile rezanja, ali i uzmajući u obzir i efekte, kao što su habanje

$$P(t) = \sum_{i=0}^{n} P_i \, B_i^n(t)$$

To podrazumeva da svaki *P(t)* ima x, y i z koordinate. Segmenat određene dužine (npr. u veličina uzima vrednost 0.02 definisana u primeru) prolazi kroz matematički definisanu krivu, što znači da će ceo luk dužine krive biti podeljen na 0.02 i rezultujuća vrednost će biti broj koordinatnih vrednosti alata kojim će proći. Ovaj program se odnosi na primenu i korišćenje na Siemens upravljačke jedinice. Opšti koncepti se odnose na skoro svako CNC upravljanje koje može da omogući i realizuje parametarske programske funkcije. Rezultati i diskusija usmerena je na tačnost izrađenog profila. Putem parametara deficisna je kriva i prirast veličine *u.*

alata, uticaj sile stezanja, itd. Rezultati parametarskih programa sprovedenih navedenom metodologijom daju znatna poboljšanja tačnosti na analiziranim, eksperimentalnim radnim premetima, što autori i predstavljaju dijagramski navodeći mogućnosti proširenja analize uvođenjem alata i geometrijskih i termičkih grešaka.

Jedno od osnovnih pitanja koja se nameću vezana su za način dobijanja vrednosti parametara koji se koriste u parametarskom programiranju. Najjednostavniji metod definisanja parametarskog programa, pa i samih parametara, ogleda se u projektovanju tipskog dela korišćenjem CAD-CAM softvera, a dobijeni NC program preradi u makro program što ukazuju u svom radu grupa autora M.A. Razak, M.R. Ibrahim, and all. u radu [3]. Standardni CAM softver koristi standard ISO 6983 koji prvo identifikuje mašinske funkcije i automatski generiše standardni NC deo programa. Većina nedavnih radova koji se bave obradom prvenstveno su se fokusirala ka novim standardima ISO 14649 (data model for computerized numerical control) i ISO 10303-238 (application interpreted model for numerical controllers). STEP-NC način programiranja terminološki i sintaksno nosi strukturu određenu makro programiranja, koja komplesnije razmatra proces makro programiranja, jer uključuje podatke o alatu, materijalu, strategijama obrade i dr. navodi se u radovima [11] , [17] i [14]. Sa stanovišta primenljivosti većina upravljačkih jedinica nije u mogućnosti da realizuje ovu vrstu programa jer zahteva odgovarajuća prevođenja razumljiva upravljanju, koja je reprezentovana preko dva scenarija; korišćenje STEP-NC programiranja i konverzija u G-kod i preko CAD-CAM softvera kreirati STEP-NC i potom kovertovati ga u G-kod [17].

3. METODOLOGIJA

Redosled operacija i zahvata u teoriji rezanja je poznat za pojedine vrste obrade. Ova činjenica je omogućila kreiranje ekspert zananja tj. ekspertskih sistema. Ovi poslednji prouzrokovali su stvaranje takvih CAM sistema koji vode korisnika pri projektovanju tehnološkog postupka od početka do kraja, nudeći mu izbor različitih strategija obrade u adekvatnom trenutku projektovanja. Taj i takav način (posmatrajući ga i manipulativno) ostao je nepromenljiv do danas. Projektant tehnološkog postupka u dijalogu sa CAM softverom unosi adekvatne podatke, obično preko dijalog prozora. Kao, izlaz iz procesa projektovanja tj. teh. postupka je CNC program, fajl napisan u G-kodu, koji razume konkretna CNC mašina.

Značajno je napomenuti da su ovi programi posebni (važe za konkretni deo) jer sadrže samo one strategije obrade koje je projektant postupka odabrao. Razvojem hardverskih i sofverskih mogućnosti upravljačkih jedinica CNC mašina, moguće je napisati opšti CNC program, koji sadrži sve izvodljive strategije obrade, a uvođenjem promenljivih veličina sličnim iz programskih jezika (npr. C-jezika) doći do posebnosti samog programa.

Konretna mogućnost se nudi korisnicima putem parametarskog ili fleksibilnog programiranja korišćenjem naredbi tipa IF....THEN...ELSE, WHILE … DO, REPEAT … UNTIL IF…GOTOB/GOTOF (IF…GOTO) uz adekvatno definisanje ulaznih varijabli. Interperabilnost između parmatarski napisanog, opšteg programa moguće je učiniti konkretnim, čitanjem tag-a pričvšćenog za obradak primenom RFID tehnologije i njihovim spajanjem u jedinstveni program.

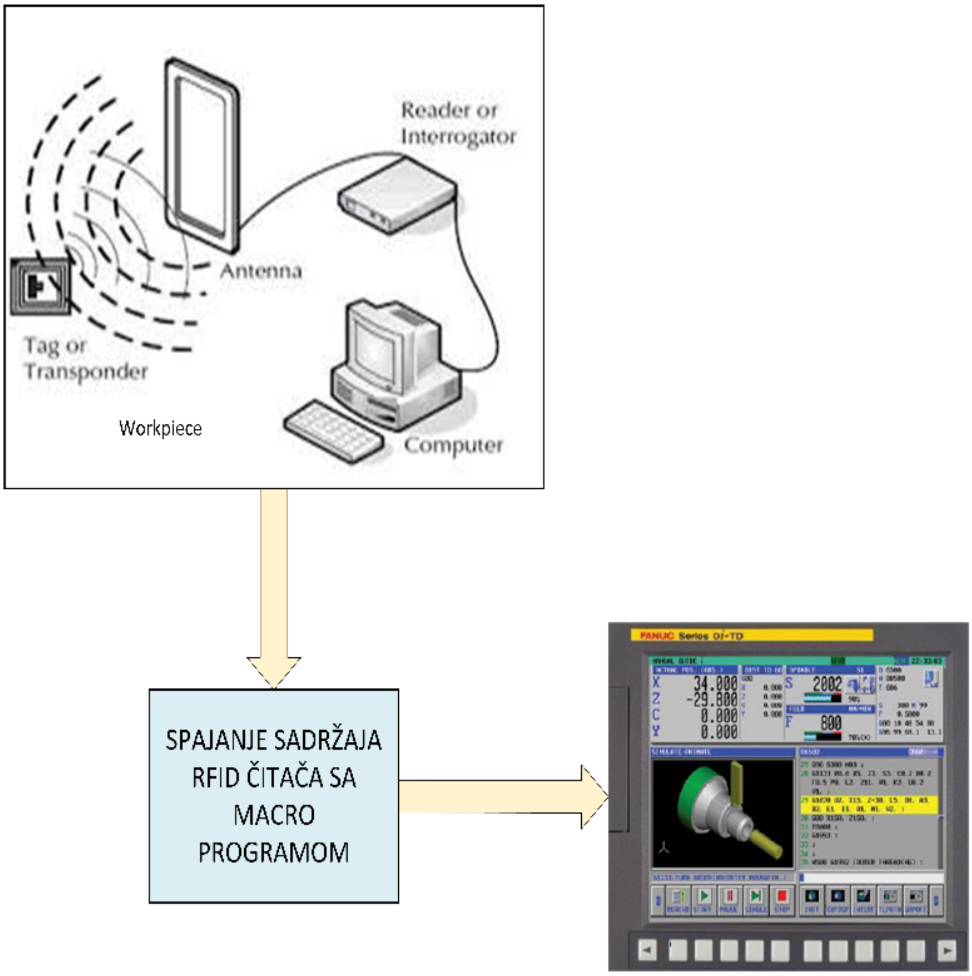
RFID – Radio frekventna identifikacija – je tehnologija koja koristi tehniku frekvencijskih radio-talasa za razmenu podataka između čitača (reader) i uređaja koji se zove transmiter (tag) / transponder (Wikipedia, RFID). Tag sadrži silikonski mikročip i antenu. Antena ima funkciju odašiljanja radio-talasa čime se podaci s mikročipa koji se putem čitača preusmeravaju u računar. Transponder se može naći i na proizvodu (češće na nosaču proizvoda, paleti) i sadrži jedinstveni serijski broj. RFID tehnologija se pretežno koristi za identifikaciju delova koje treba transportovati, ili u samom procesu ili van njega, skladištiti, privremeno ili trajno, ili periodično evidentirati, što sam sistem dovodi u kategoriju elektronskog pametnog skladištenja - (eng. smart packaging). Evidentna je primena RFID tehnologije u obezbeđivanju geometrijskih i tehnoloških parametara putem pasivnih tagova.

Transponder se aktivira pri prolazku kroz radio frekventno područje koje je generisano uz pomoć antene i čitača. Transponder zatim odašilje programirani odgovor u obliku traženih informacija. Antena koja je povezana sa čitačem i koja stvara radio frekventno polje detektuje odgovor. Čitač zatim šalje u računar podatke koje sadrži mikročip.

Jedna od značajnijih primena RFID u fleksibilnoj proizvodnji je identifikacija i praćene delova u sistemima upravljanja transportom. Relativno mali broj istrživača se bavio primenom RFID tehnologije u programiranju CNC mašina.

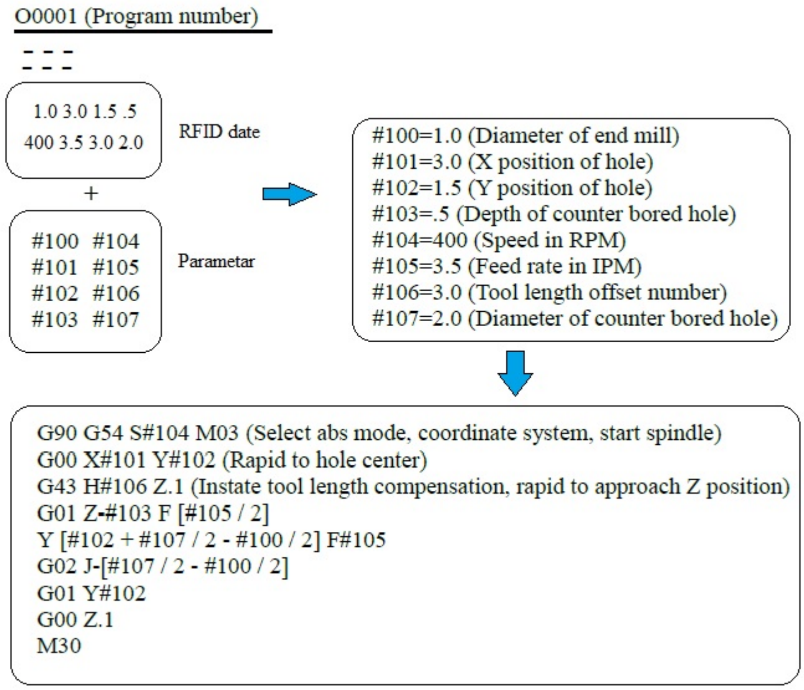
Postojeći sistemi upravljanja imaju slabiji dinamički odziv sistema, posebno u slučajevima kada su delovi manjeg gabarita, velike konfiguracione raznolikosti ili male učestalosti pojavljivanja. Uvođenjem RFID tehnologije u upravljanja, naročito, FMC-a (FMS-a) moguće je sistem decentralizovati i prilagoditi upravljanje novim uslovima.

U ovom radu daje se nova dimenzija primene parametarskog makro programiranja (ili fleksibilnog programiranja) koja parametre obrade preuzima iz okruženja, pročitanog sa taga koji je zalepljen za radni predmet (sa RFID čitača) povezujući ih sa relevantnim parametrima koji se u konačnom obliku spajaju sa makro programom (opštim programom) što je prikazano blok šemom na Slici 1.



Slika 1. Proces spajanja eksternih informacija sa makro programom

Najjednostavniji primer gore predočenog procesa je primer makro programa za proces bušenja koji iz okruženja dobija geometrijske i tehnološke informacije CNC programa. Primer sa Slike 2. je izveden u Macro „B” sistemu parametarskog programiranja (upravljačke jedinice FANUC, FADAL, ..). Metodologija parametarskog programiranja za slučajeve krivih linija uz interperabilnost RFID tehnologije je suštinski modifikovani oblik prikazan u radu [13]. Evidentno je da podatke vezane za definisanje krive, veličine segmenta, dubine, kao i prirast ovih veličina su podaci zapisani na tagu, a prosleđuju se putem čitača upravljanju. Ova metodologija je prikazana je algoritamski na slici 3.



Slika 2. Primer makro programa za obradu bušenja

Prema [8] i [12], parametri u sistemima (upravljačkim jedinicama) SINUMERIK su posebne memorijske lokacije koje su na raspolaganju korisniku da bi se u njih unele konkretne vrednosti. Uneta vrednost pridružuje se konkretnom parametru. Na primer R55 lokaciji pridružuje se vrednost parametra 33.33. Ovaj podatak moguće je unetu u upravljačku jedinicu manipupulacijom operatera ili programski R55=33.33. Dozvoljene su arimetičke operacije nad parmetrima npr.

R1=R2+R3,
R4=R5-R6,
R7=R8*R9,
R10=R11/R12 R13=SIN(25.3), ili

R1=R1+1 (novo R1= staro R1+1) itd.

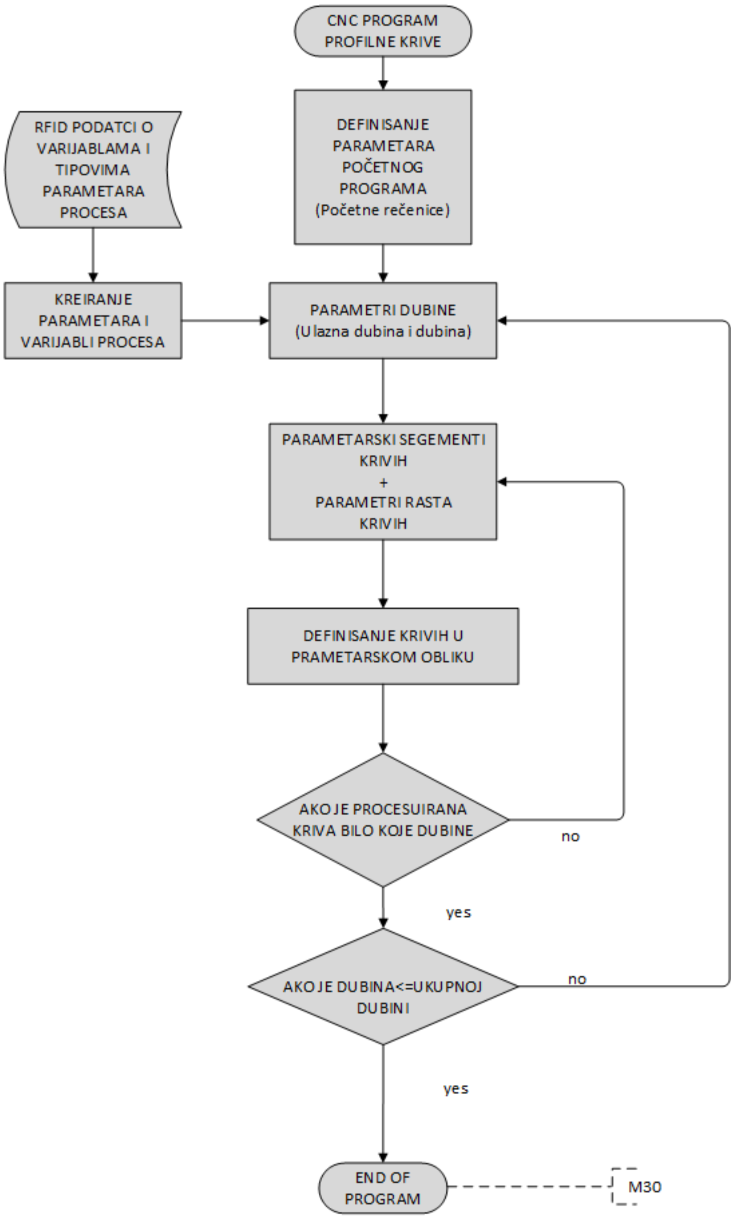
Primeri poređenja:

IF R11>=100 GOTOF DEST
ili
R12=R11>=100
IF R11 GOTOF DEST
Rezultat poređenja R10>=100 is first buffered R11

U fleksibilnom programiranju zastupljene su operacije poređenja koje su predstavljene u Tabeli 3.

Tabela 3. Operatori poređenja

operacije poređenja	**značenje**
==	jednakost
<>	nejednakost
>	veće
<	manje
>=	veće ili jednako
<=	manje ili jednako
<<	menjanje stringa



Slika 3. Logika programiranja krivih linija sa interperabilnošću RFID tehnologije

Logičke operacije se koriste za logičko kombinovanje pravih vrednosti. AND, OR, NOT i XOR (Tabela 4.) mogu generalno biti korišćene promenljive tipa BOOL, koje mogu biti primenjene na tipove podataka CHAR, INT i REAL (Tabela 5.) sa značenjima implicitnih tipova konverzija. Razmaci moraju biti unešeni između bulovih operanata i operatora. U logičkim (bulovim) operacijama važi sledeće za tipove podataka BOOL, CHAR, INT i REAL:

- 0 ekvivalentno NETAČNO

nije jednako 0 je ekvivalentno TAČNO

Tabela 4. Logičke operacije

Operator	**Značenje**
AND	i
OR	ili
NOT	ne
XOR	obavezno ili

Tipovi promenljivih mogu biti**:** promenljive koje definiše korisnik, aritmetički parametri i sistemske promenljive.

Prema [1] definisanje korisničkih varijabli počinje sa komandom DEF koju prati sintaksa:

DEF <variable type> < variable name> = <variable value>

Tabela 5. Tipovi promenljivih i opseg njihovih vrednosti (pruzeto iz [1])

Tip	**Definicija**	**Dozvoljeni opseg vrednosti**

varijable		
INT	Integer numerička vrednost	-2147483646 ... +2147483647
REAL	Brojevi sa decimalnom tačkom	$\pm (2,2 * 10^{-308} ... 1,8 * 10^{+308})$
BOOL	Logičke vrednosti: TRUE (l), FALSE (0)	1 ili 0
CHAR	ASCII karakter	Posebno , saglasno ASCII kodu, moguće je dodeljivanje srpskih karaktera
STRING	Lanac znakova u zagradi [ ]	Može se definisati do 200 znakova
AXIS	Identifikatori osa (adrese)	Identifikatori osa ili vretena koji su definisani datim kanalom
FRAME	Geometrijska transformacija koordinatnog sistema	

Sistemske promenljive mogu biti upotrebljene u programu. Sistemskim promenljivim je obezbeđen pristup do zero offset, tool offset, aktuelnih vrednosti, izmerenih vrednosti na osama, control states, itd. Sistemske promenljive vraćaju vrednosti definisanog tipa. Nekim sistemskim promenljivim ne mogu biti dodeljene vrednosti. Ime sistemskih promenljivih uvek se indentifikuje pomoću "$" karaktera praćen specifičnim imenom.

Prvo slovo	**Značenje**
$M	Podaci mašine
$S	Podešavanja podataka
$T	Upravljanje podacima alata
$P	Programirane vrednosti
$A	Aktuelne vrednosti
$V	Servisni podaci
Drugo slovo	**Značenje**
N	NCK-globalno
C	Kanal-poseban
A	Osa-posebna

Tabela 6. Sistemske promenljive

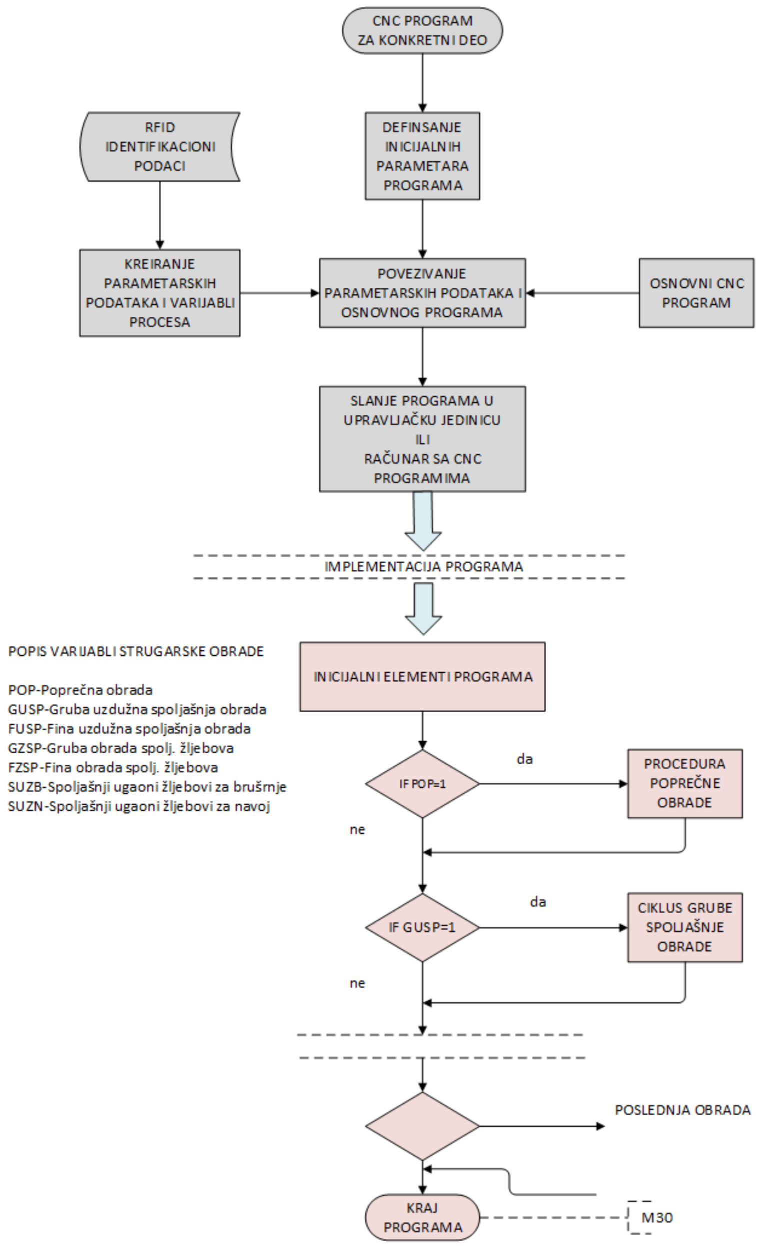
Zagrada može biti korišćena u aritmetičkim izrazima da definiše redosled izvršenja za sve operacije i da bi ponistio normalan redosled računanja.

Na primer:

```
IF(R10<50) AND ($AA_IM[X]>=17.5) GOTOF DEST
IF NOT R10 GOTOB START
```

Kad je CNC mašina uključena u fleksibilnu proizvodnju tj. FMC/FMS tada možemo govoriti o ograničenoj fleksibilnost kao posledici brze izmene programa koja dirktno utiče na opterećenje računarskih resursa. Nedovoljna brzina odziva na brze promene proizvodnog programa kod klasičnih mrežnih okruženja, na relaciji ćelijski server FMC (računar) - DNC računar - CNC mašina može biti potencijalno nedoknadiva primenom RFID tehnologije, koja se ogleda se u povećanju sposobnosti podređenih računara unutar sistema. Tada računari unutar sistema dobijaju na značaju u odnosu na pređašnju delimičnu autonomnu kontrolu, postaju autonomni i nisu zavisni od servera.

Ako se opštem CNC programu pridodaju parametri (u razmatranju za SINUMERIK upravljačke jedinice to su R parametri) i promenljive koje se odnose na zahvate unutar operacije, koji su pročitani sa tag-a zalepljenog za radni predmet, tada oppšti program postaje poseban tj. onaj koji se odnosi na konkretan radni predmet. Na slici 4. prikazana je blok šema programa namenjena obradi struganjem. Tehnološki postupak je poznat, redosled zahvata je tačno određen, produkt je ekspert znanja, a kao takav je sastavni elemenat u domenu klasične CAD-CAM tehnologije za obradu struganjem.



Slika 4. Blok šema fleksibilnog programiranja za proces obrade na strugu

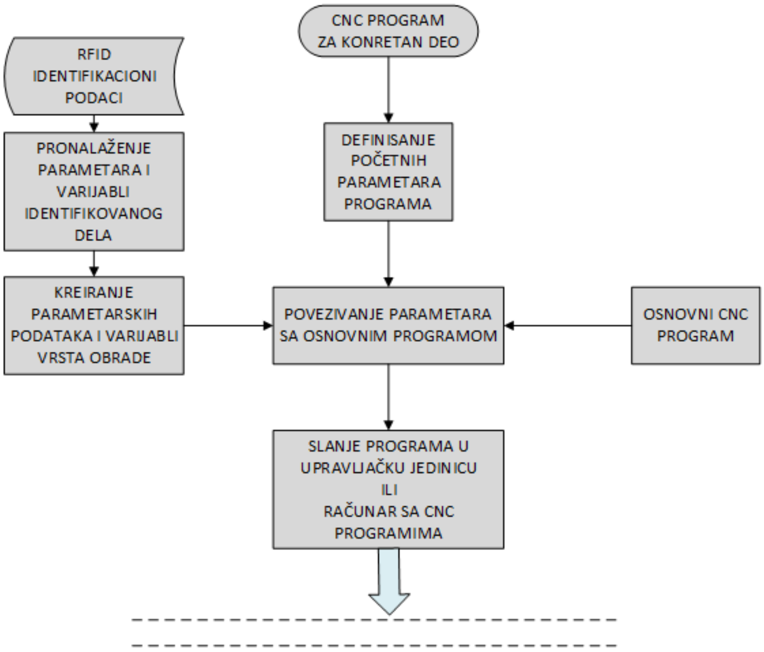
Zapisi pročitani sa RFID čitača prevode se u oblik pogodan za spajanje sa opštim CNC programom (makro programom). Strukturno posmatrano novonastali fajl čine R parametri koji korespondiraju sa odvarajućim parametrima procedura/ciklusa opšteg programa, i varijable zahvata obrade koji mogu uzeti vrednost 0 ili 1. Ako je vrednost varijable zahvata 0 tada posebni program ne izvršava taj zahvat. Ovaj iskaz u blok dijagramu odgovara grani IF naredbi „ne". Suprotno ako varijabla zahvata uzme vrednost 1 tada se izvodi deo programa namenjen toj proceduri/ciklusu. CNC program je autonoman, a redosled zahvata u okviru operacije je utvrđen na bazi ekspert znanja tj.tačno definisan.

Ako bi se ukazala potreba za promenom redosleda zahvata u operaciji (slučajevi kad korisnik iskustveno ima saznanja i potrebu za drugačijim redosledom zahvata), korisnik može samostalno pristupiti izmeni opšteg CNC programa, što iziskuje dobro poznavanje programiranja u G kodu i fleksibilno programiranje.

Ograničavajući faktor predočen u predhodnoj metodologiji je kapacitet memorije na RFID tag-u. Iz tih razloga daje se modifikacija predhodne metodologije.

Naime iz RFID tag-a dobijaju se informacije o identifikaciji radnog predmeta. U računaru pronalaze se predhodno definisani parametri i varijable koje se potom spajaju u jedinstveni program. Na slici 5. prikazana je blok šema ovog modifikavonog fleksibilnog programiranja.

Za CNC programe enormno velikih dužina i dalje ostaje mogućnost njihovog kreiranja primenom programiranja u CAD-CAM softveru. RFID tehnologije u ovom i ovakvim slučajevima primene služi samo za identifikacija radnog predmeta, a preko nje pronalaženje programa u memoriji računara.



Slika 5. Modifikovana blok šema fleksibilnog programiranja

4. REZULTATI ISTRAŽIVANJA I PRAVCI RAZVOJA

U prvom eksperimentalnom delu razmatrane su tri grupacije delova sa pet različitih vrsta obrade na strugu, bez korišćenja povratnih sprega u programu, a poređenje je analizirano za dva načina programiranja; G-kod i parametarsko programiranje. U drugom eksperimentu analizrani su parametarski interperabilni programi primenom RFID tehnologije na glodalici, čije algoritamske strukture sadrže korišćenje povratnih sprega. Testirani su programi 2½D geometrije čiji fičeri su podržani od većine upraljačkih jedinica.

Testirani programi za sprovedene analize (za obe vrste obrade) rezultiraju poboljšanju efikasnosti NC operacija sa aspekta: brzine izmene programa, realizacije većeg broja programa u istom vremenskom intervalu, kraća dužina programa, povećana fleksibilnost za grupu sličnih delova i rasterećenje računarskih resursa. Dobijeni rezultati na polju implementacije MACRO programiranja primenom RFID tehnologije mogu se koristiti za povećanje:

- fleksibilnosti tehnološkg postupka,
- optimizaciju i unapređenje procesa (tehniku i tehnologiju postupka), i
- podizanje nivoa izučavanja.

Rezultati su teorijski i praktični i imaju aplikativnu primenu u fleksibilnim proizvodnim sistemima. Sa povećanjem kapaciteta memorije na transporderima omogući će se da kompletni parametri za sve, pa i one duže programske sadržaje, zapišu i koriste u tehnološkom procesu. Do ostvarenja takvih mogućnosti može nas voditi put ka višestrukom čitanju memoriskog zapisa i promeni njegovog sadržaja na transponderu u zavisnosti od mogućnosti koja od mašina je slobodna i spremna da primi u proces obrade konretan radni predmet. Jedan od pravaca vodi i ka razvoju novijih upravljačkih jedinica koja poded G koda su u mogućnosti da pročitaju STEP- NC program koji se može takođe naći na transporderu i biti pročitan, a potom i realizovan u svom obliku.

5. ZAKLJUČAK

Primena fleksibilnog CNC programiranja svoj puni efekat daje u slučajevima kada je CNC mašina sastavni deo FMC/FMS, a delovi su manjeg gabarita sa brzom i učestalom promenom proizvodnog programa. U tim slučajevima može se govoriti i o karakteru adaptivnog upraljanja procesom, jer je sadržaj programa opšti, a varijable su te koje odrđuju izvođenje pojedinih strategija obrade tj. zahvata. Vrednosti parametara daju poseban ton tehnologičnosti procesa obrade i njihova vrednost ima veoma važnu ulogu u samom procesu. Kao što je predhodno izneto računari unutar mrežnog okruženja sada imaju potpuno novu ulogu; imaju određeni stepen autonomnosti i nisu u toj meri podređeni serveru.

Na osnovu izloženog proističe mogućnost projektovanja novih softverskog paketa, koji će omogućiti podršku fleksibilnijoj i efektivnijem procesu u oblasti fleksibilne proizvodnje.

Naučni cilj rada je istraživanje, razvoj i implementacija RFID tehnologije u upravljačke sisteme fleksibilnih obradnih sistema. Ostvarivanje osnovnog cilja, unapređenje procesa, realizuje se kroz sledeće parcijalne ciljeve koji će poslužiti kao osnova za: automatsku identifikaciju proizvoda na bazi RFID tehnologije, planiranje tehnološkog postupka na osnovu zapisa tagova, i rasterećenje upravljačkog sistema tj. lokalizacija upravljanja.

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RFID Technology in the Service of Flexible CNC Programming

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In this article new approaches are made in parametric programming CNC machines. RFID technology can give a good basis as a carrier of technological and geometrical information especially if the machine is turned on within the flexible production of parts the container and bigger frequency. Parametric programming of this type can be one of the links that will lead it to adaptable controlling in real time.

Keywords: RFID – Radio Frequency Identification, Parametric programming, CAD/CAM, DNC-Direct Numerical Control

1.INTRODUCTION

Constructional requests regarding manufacturing parts, have forced development of new control units, as with elements of both hardware and software. In this article, the accent will be directed only towards the software components of the control units that are associated with parametric programming. Terminologically viewing under the concept of parametric programming, depending on the manufacturer of the control units, synonyms are encountered: macro programming and flexible programming. Historically looking at control unit manufacturers, in their earliest stages of production, didn't have the intention of giving the user the capability to use parametric programming. However the very need imposed upon them due to the development of more sophisticated constructional solutions in CNC machines, the complexity of the designs for manufacturing, the pursuit towards faster programming, especially in type/group tech, has necessarily imposed the implementation of this kind of programming into the software solutions of control units. Parametric programming is not unified and depends on the manufacturer of control units, thus the analysis has shown that there are unknown deviations within one type of control unit. Studying literature [5] and [6], we have come to the fact that other control units from different manufacturers have the same type of parametric programming, while other control unit manufacturers have developed a special language relevant for parametric programming.

In this short review of development and implementation of parametric programming, it should be noted that with today's degree of programming, this type of programming takes the user's level of programming program languages several years back (type BASIC).

The usefulness of parametric programming brings, undoubtedly, advantages that are reflected on the speed of its work on the written program, smaller occupation of program memory which is the result of shorter programs when compared to the typical kind (G code) [3].

Development of RFID technology opened up the possibility for a different approach for this kind of programming of CNC machines. Expected results in the field of parametric (MACRO or flexible) programming in association with RFID tech can give benefits with the goal of increasing: the flexibility of the technological process, the optimization and upgrading of the process, creation of CNC programs while in the phase of identification of the part and possibility of changing the technological process while it is in the phase of the process (in case of flexible production). Contributions to this approach of designing the process are especially effective and flexible.

The primary goal of this work is the investigation, development of the design process using MACRO or flexible programming in interoperability with RFID technology. Despite the aforementioned the secondary goal of this work is devising fast, controlling of unknowns, ad hoc, unplanned solutions, that while in the process of projecting, are on their own bringing closer the process to the adaptive level.

From the aforementioned, from now on, in the following chapters, the directions of investigators and analysis of parametric programming within relevant literature are presented and the fundamentals of RFID technology, the methodology and results of the investigations, are given.

2. LITERATURE REVIEW

According to the analysis undertaken regarding user literature as well as in multiple control unit manufacturer recommendations:

- Programming a family of parts,
- Defining specific cycles,
- Specific construction features that are repeated,
- Complex program movement, as well as parable, ellipsis, etc.
- Specifically installed additional equipment (for example measuring equipment)
- "Smart" programs, and
- Macro programs that can bring decisions with the help of conditional statements

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Listed accordingly, specifications of singled out scientific works are given in short one of the first works of parametric programming that are taken into consideration is the work „A Parametric Programming Technique For Efficient CNC Machining Operations” authored by Manocher Djassemi [9]. The author quotes the definition of parametric programming stressing that: parametric programming is G / M coded programming in which the positions of the axis (x, i, z, a, etc.), the function of the feed and speed can be defined with parametric expression/s and that, that way of programming is similar to programming languages such as Pascal or C, in which the computers functions like the variables, arithmetic, logical statements and program loop can be programmed in a parametric way. In the work, the application of parametric programming on the basis of grouping similar designs and grouping on the basis of process requirements are mentioned. The author introduces concepts related to the techniques of parametric programming such as:

- Feature-Base CNC programming listing some of the modules of parametric programming such as Hole, Pocket, Thread, etc., and
- Repeated features whose cases of parametric can find application in situations where multiple appearances of features have different dimensions

The application of both types of programming are visited within the composition of the modules in the main program.

In the very work, through examples, both views of programming are presented and compared to in parallel, classic CNC programming and parametric programming for both of the mentioned types, highlighting, in the very conclusion, the advantages of parametric programming that visited in: simple and fast programming as well as decreased program length.

Variable types have an important role in parametric programming that, are asserted in the text Variable in Custom Macro Mike Lunch [21]. They are classified by five types of user based Macro variables; Letter address arguments, local variables, common variables, (that return into the previous state upon the deactivation of the machine), constant common variables (that are kept even after the machine is deactivated) and system variables that are used to access relevant CNC functions. Stable/unstable variables are specially separated, giving advice to future users in which way they should use these types of variables.

The ascertainment that the local variables are unstable because upon the deactivation of the machine they lose their activity, in contrast to stable variables, which the author suggests in cases where the instability causes some kind of problem. His ascertainments apply to examples of both cases. An example of applying local variables confirms that after the realization of milling (cutting) all threads of this variable are unnecessary. In contrast, stable ones can be used in multiple programs, for example for ones where the same speed and feed apply, thus even after deactivating the machine they are active. This kind of approach has obvious benefits in regard of decreasing the number of variables. Upon usage of the variables, users must have a specific amount of awareness. A part of constant common variables must always be present, especially in cases when they are present in the use of specific tools and devices for measuring (spindle touch probe).

Parametric programming from the standpoint of complex unsymmetrical structures with special accents regarding the computation of the execution speed of programming instructions and the movement speed is the subject of Grzegorz Nikiel in the work [12]. Given that the analysis is undertaken using control units Sinumerik 810D, that does not mean that it is not methodologically changeable nor are the other control units. The problem analyzed during the investigation can be carried out by: the computation of the speed of the integer variable, real variables, defining complex functions on the basis of quadratic functions (x^2),the speed of calculations for complex arithmetic expression – in one block and in several blocks with degradation of simpler computation speeds with the usage of different structures of commands -WHILE … ENDWHILE, REPEAT … UNTIL, FOR.. ENDFOR, IF…GOTOB/GOTOF and the estimated speed with the usage of subprograms. For the sake of comprehensive analysis and understanding, the basics of parametric programming are also given for this type of control and variables that are used as examples for optimizing comparative parameters. The conclusions implemented on the basis of the mentioned are led to suggestions which the programmers that use parametric programming have in mind (not just Siemens Control), with the end goal being the faster execution of programs, and they are referred to:

- Application of calculating with parameters (R-parameters) for which the computation speed for different variables (integer, real) is approximate,
- Avoiding the application of conditional instructional jumps (IF…GOTOx) in favor of other structural instructions (WHILE … DO, REPEAT … UNTIL etc.), and
- Avoiding the use of subprograms, which brings specific decelerations upon the completion of the program

As a result of experimental measuring, the computation of the operations speed, with variables distinguish themselves in hindsight tabular allegation as a result of the investigation, which once summarized can be consolidated in the following manner:

- The execution speed of the parametric program with the application of the R parameter in regard to LUD,
- Using heap and not using heap, and

Table 1. Comparing Macro and classic (Ordinary manual) programming (taken from [10])

Ordinary manual programming	**Macro Programming**
Use only constants	Use variables and assign values to variables
Not operations between constants	Operations between variables can
Program can only order, cannot jump	Program run can jump
Ordinary manual programming	Macro Programming

Unused subprograms in regard to programs, gives higher speed for realizing programs. From the supplied information we can analyze and conclude which key elements of the program as well as the kind of programming have a dominant effect on the speed of the execution of the program. Also additional elements that can cause deceleration of the execution speed of the part regarding the programs structure (such as numeration of the blocks, commentary, etc.) are mentioned.

Works that dabble with the difficulty based on specifications of the same process should be specifically noted: geometrically (firstly due to fluidity) as well as technologically (specifications of both group and type models of processing). For these reasons, from now on works that corroborate this ascertainment are given.

The work of Zhu Xiurongand and Zhand Guangcheng in their scientific work [10] apart from the scientific benefit in the field of processing technology on the thin wall bandsaw elements, give the introduction about parametric programming a table of comparable possibilities of classic and parametric programming (Table 1.), pointing out in their allegations the ease of modifications and readability of Macro programs in comparison to classic, orderly programming.

Curvy lines have a specific suitability regarding their use in parametric programming in the following industries: automobile and shipbuilding, then with extrusion tools, tools for roll forms, turbine profiles and others, and they are presented in [13]. CAD software's use parametric curves forming them within the limits of upper and lower deviations, with the goal being, the development of the adequate part. The smaller the deviation limits, the bigger the process's accuracy which the CAM software generates. Parametric programming must possess the curve equation through which the geometry can be controlled through the shifting of parameters. The mentioned work, for example, takes and presents parametric programming through Beziers profile curve lines as representatives of this kind of grouping of curve lines that are relevant to the equation given in the form of:

$$P(t) = \sum_{i=0}^{n} P_i \, B_i^n(t)$$

This implies that every $P(t)$ has x, y and z coordinates. Segments of specific length (for example the u value is given the 0.02 value that is defined in the example) go through a mathematically defined curve, which means that the whole angles curve length will be divided into 0.02 and the resulting value will be the number of coordinate values of the tool that will pass. This program is referred to the application and usage on Siemens control units. The basic concept is referred to almost every type of CNC control which can enable and realize parametric programming functions. The results and discussion are directed towards the correctly produced profile. Via parameters, the curve is defined as well as the growth of the u value.

With CAM technology, the accent of accuracy is based upon the upper and lower deviation from the Bezier profile within whose limits the interpolation lines are spread out. When the Bezier curve is realized via parametric programming, then the parameter u (increment) depends on the choices of the user as well as the parameters of the processing. By increasing the number of these parameters, the number of incremental lines are also increased, which directly affects the accuracy of the process. The authors display the results of the process in Table 2.

The author in the work [20], on the basis of theoretical settings linked with other deformations under the effect of component penetration (F_x), and taking into consideration the mistakes that are made: as a result of the rigidity of the work piece, via clamping tool and clamping assembly, introduces and presents theoretical settings which are implemented in parametric programming which are removed, that is to say, the mistakes in the process are compensated for i.

Complete analysis is carried out for biaxial CNC machines (CNC lathe center) giving the mathematical model for 2 geometrical shapes stressing that are mistakes as a result of: geometrical mistakes are inherent for machine tools, thermally inducted distortions and static deformations on processing systems that are a result of clamping force, but the effects are also taken into account, as well as wear tools, the effect of clamping force etc.

Table 2. The results of comparative analysis of CAM programming and parametric programming (taken from [13])

Features of Comparison	**Curve-Curve**		**Arc-Line**		**Curve-Line**		**Arc-Arc**		**Arc-Curve**	
	CAM System	Parametric	CAM System	Parametric	CAM System	Parametric	CAM System	Parametric	CAM System	Parametric
Number of Blocks/NC instruction lines	2055	53	1229	41	1424	41	1875	41	1754	41

Machining Cycle Time		1M 9S	1M 8S	1M 28S	1M 12S	1M 24S	1M 9S	1M 46S	1M 23S	1M 37S	1M 20S
Accuracy	Minimum	-0.878	-0.202	-0.983	-1.023	-0.523	-0.632	0.862	0.523	-0.142	0.093
	Maximum	0.138	0.906	0.815	0.593	0.340	0.847	0.639	0.794	0.236	0.998
	Average	-0.127	0.129	0.272	0.019	0.204	0.264	0.227	0.055	0.048	-0.058
	RMSE	0.400	0.255	0.518	0.267	0.195	0.121	0.501	0.249	0.407	0.334

The results from parametric programs undertaken via aforementioned methodology give substantial improvements in regards to the accuracy of the analysis, experimental work pieces, which the author introduce by leading the possibilities of the analysis's expansion by implementing tools and geometric and thermal mistakes via diagram. One of the basic questions which are imposed related to the acquisition of values which are used in parametric programming. The simplest method of defining in parametric programming, as well as the very parameters are visited in the designing of a typical part using CAD-CAM software, and the received NC program rewrites into macro programming which is shown in the group work of authors M.A. Razak, M.R. Ibrahim, and all in the work [3]. Standard CAM software uses the standard ISO 6983 which firstly identifies machine functions and automatically generates the standard NC bit of program. The majority of recent works which are about processing were firstly focused on new standards ISO 14649 (data model for computerized numerical control) and ISO 10303-238 (application interpreted model for numerical controllers). STEP-NC type of programming is terminologically and syntactically carries the structure of specific parts of macro programming, which considers macro programming in a more complex manner, because it includes data about tools, materials, strategies of processing and others are mentioned in works [17] and [14]. From the viewpoint of applicability, the majority of control units isn't capable to realize this kind of program because its requires appropriate translations that the control can understand, which is represented by two scenarios: using STEP-NC programming and conversion into G code and via CAD-CAM software create STEP-NC and then convert it into G code [17].

3. METHODOLOGY

The order in which the operations and grip in cutting theory is known for certain types of processing. This fact enabled the creations of expert knowledge, that is, expert systems. These last ones have caused the creation of such CAM systems which can lead the user during designing of the technological process from start to finish, offering him an array of different processing strategies in adequate design moments. This and that way (observing him in a manipulative manner) has been left the same to this day. The designer of the technological process during the dialog with CAM software types in the adequate data, usually over the dialog window. Exiting the design process, that is, the technological process is the CNC program, a file written in G code, which the CNC machine understands.

It's important to mention that these programs are special (they apply to a specific part) because they contain only those processing strategies which the designer chose. The development of hardware and software capabilities of control units for CNC machines, it's possible to write a basic CNC program that contains all possible processing strategies, but implementing similar variable values from program languages (for example C) can lead to the uniqueness of the program.

A proper possibility is offered to users via parametric or flexible programming using orders type IF....THEN...ELSE, WHILE … DO, REPEAT … UNTILIF…GOTOB/GOTOF (IF…GOTO) with adequate definition of on entry variables. Interoperability between a parametrically written, basic program it's possible to make a concrete reading of tag tightened to the work piece using the RFID technology and their merging into a unique program.

RFID – Radio frequency identification - is a type of technology which uses a technique based upon radio wave frequency for the exchange of data between readers and the device that is named the transmitter (tag)/transponder (Wikipedia, RFID). Tag contains a silicone based microchip and an antenna. The antenna has the job of transmitting radio-waves where the data from the microchip is, via the reader, redirected to the computer. The transponder can be found on the product as well (usually on the product carries, pallet) and it contains a unique serial number. RFID technology is mostly used for the identification of parts that need to be transported, or in the very process or out of it, storing it, temporarily or permanently, or periodically evident it, which brings the system into the category of electronically smart storage – (smart packing).

The application of RFID technology is evident in securing geometrical and technological parameters via passive tags. The transponder is activated if it's within a radio frequent field which is generated with the help of the antenna and the reader. The transponder then transmits the programmed answer in the form of the needed information. The antenna is linked with the reader which creates a radio frequent field detects the answer. The reader then sends the data containing the microchip into the computer.

One of the significant uses of RFID in flexible production is the identification and tracking of parts in transport control systems. A relatively small number of investigations have dabbled with the application of RFID technology in CNC machine programming. Existing control systems have a weaker dynamic system response, especially in cases where the parts have smaller dimensions, bigger configuration variety or small frequency of occurrence. Implementing RFID technology into controls, especially, FMC (FMS) it is possible to decentralize the system and adjust it to new control conditions.

In this work, new dimensions are given use in parametric macro programming (or flexible programming) which takes the process parameters from the surroundings, read from the tag which is glued onto the work piece (from the RFID reader) connecting them with relevant parameters that in their final form merge with macro program (basic program) which is shown in the Fig. 1.

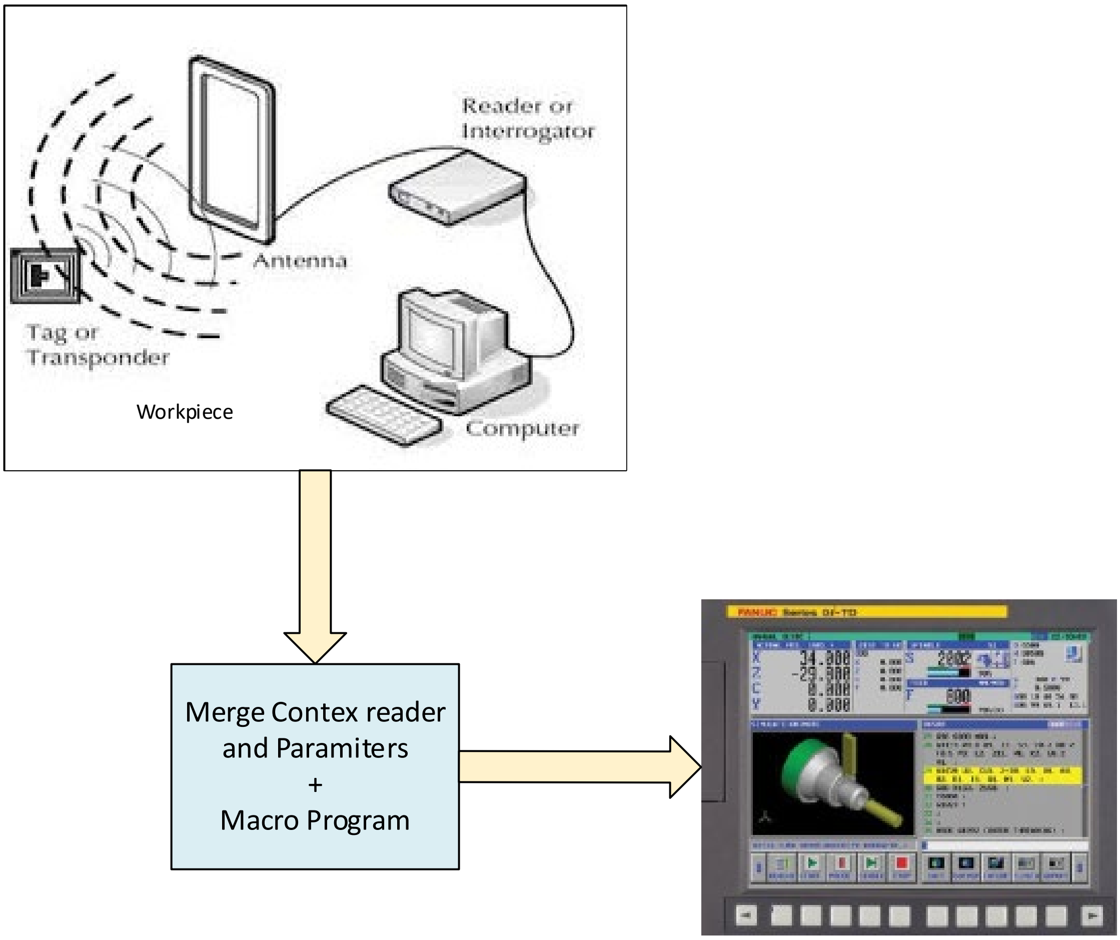

Figure1: The process of merging external information with macro programming

The simplest example of either process is the example of macro programming for drilling which gains geometrical and technological information for the CNC program is received from its surroundings. The example, from Fig 2., is implemented in the Macro „B” parametric programming system (control units FANUC, FADAL, ...). The methodology behind parametric programming for curve line cases with the interoperability of RFID technology is essentially a modified shape displayed in [13]. It is evident that the data linked with the defining of the curve, dimensions of the segments, depth, as well as the growth of these dimensions are data recorded on the tag, and are forwarded via reader control. This methodology is shown algorithmically in Fig. 3.

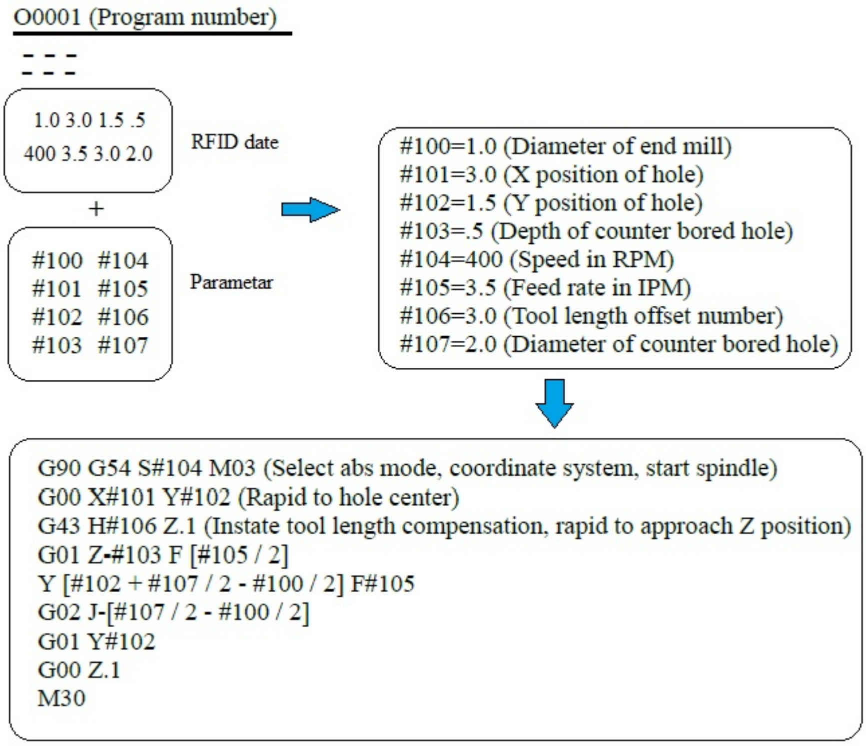

Figure 2: Example of the macro-processing program of drilling

According to [8] and [12], parameters in SINUMERIK systems (control units) are special memory locations which are at the user's disposal so that the correct values can be entered. The entered value joins the specific parameter. In example R55, the location is joined by the parameter value 33.33. This data can be entered into the control unit through the operator or through the program R55=33.33. Arithmetic operations on parameters are allowed.

R1=R2+R3,
R4=R5-R6,
R7=R8*R9,
R10=R11/R12 R13=SIN(25.3), or
R1=R1+1 (new R1= old R1+1) etc.

The flexible programming operations are represented comparisons presented in Table 3.

Table 3. Comparison operators

Comparison operations	Meaning
==	Equal to
<>	Not equal to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to
<<	Chaining of strings

Examples of comparison:

IF R11>=100 GOTOF DEST
or
R12=R11>=100
IF R11 GOTOF DEST
Result comparisons R10>=100 is first buffered R11

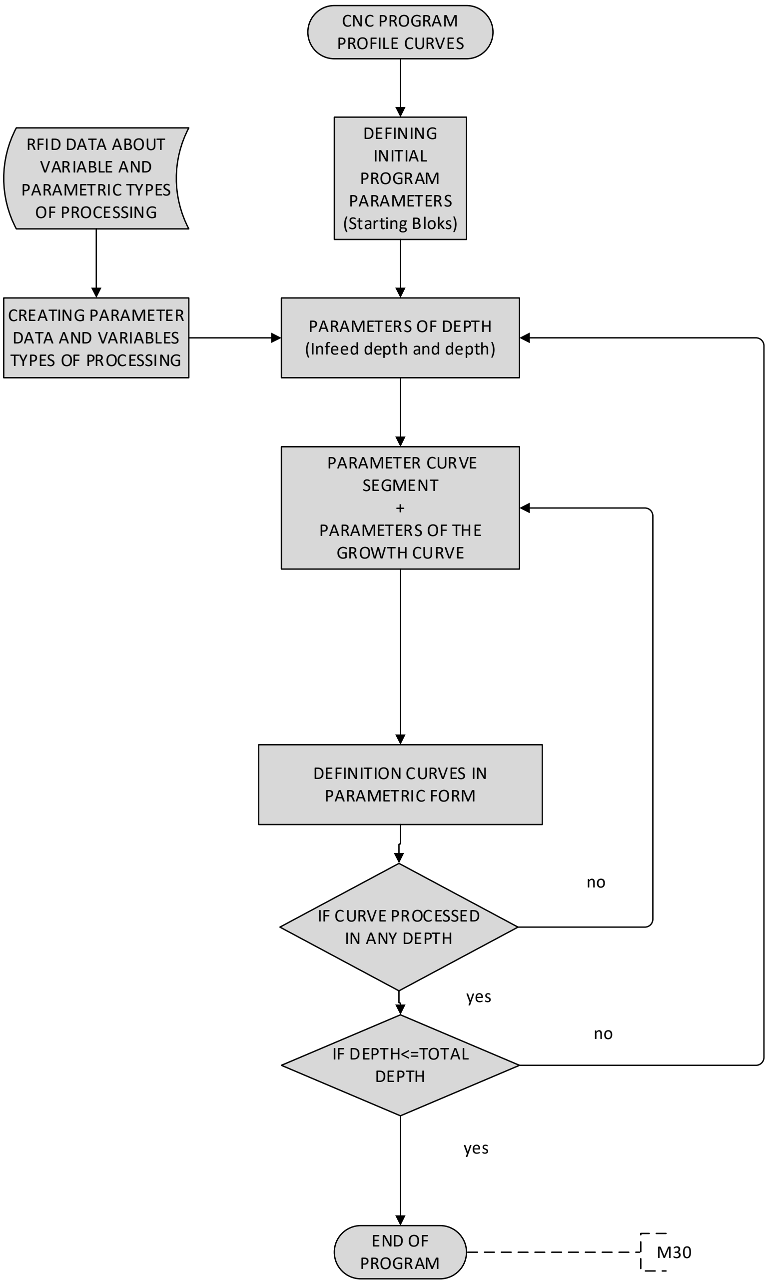

Figure 3: Logical programming of curves with interoperability RFID technology

Logical operations use logical combining of real values. AND, OR, NOT and XOR (Table 4.) can be generally used variables of the BOOL type, which can be applied on types of data such as CHAR, INT and REAL (Table 5.) with the meanings of the implicit conversion types. Spaces must be entered between BOOL's operator and the logical operator. In logical (BOOL's) operations, the following is applied for the data types BOOL, CHAR, INT and REAL:

- 0 = INCORRECT
- Doesn't equel 0 = CORRECT

Table 4. Logical Operations

Operator	**Meaning**
AND	And
OR	Or
NOT	Not
XOR	Exclusive OR

The types of variables can be: variables that are defined by the user, arithmetic parameters and system variables. According to [1] the definition of user variables starts with the command DEF which is followed by the syntax:

DEF <variable type> < variable name> = <variable value>

Table 5. The types of variables and the range of their values (taken from [1])

Type of variable	Definition	Allowable value range
INT	Integer numerical values	-2147483646 ... +2147483647
REAL	Fractional numbers with a decimal point	$\pm (2{,}2 * 10^{-308} \ldots 1{,}8 * 10^{+308})$
BOOL	Logic values: TRUE (l), FALSE (0)	1 or 0
CHAR	ASCII character	Respectively, according to the ASCII code, it is possible to assign Serbian characters
STRING	Character chain in brackets [ ]	Up to 200 characters can be defined
AXIS	Axis identifiers (addresses)	Axis identifiers or spindles existing in a given channel
FRAME	Geometrical data of coordinate system transformations	

System variables can be used in the program. The systems variables are assured access until zero offest, tool offest, actual values, measured values on the axis, control states, etc. The systems variables return the values of the specified type. Some system variables can't be given values. The names of the system values can always be identified with the ”$” character followed by a specific name.

Table 6. System Variables

1st letter	Meaning
$M	Machine data
$S	Setting data
$T	Tool management data
$P	Programmed values
$A	Current values
$V	Service data
2nd letter	**Meaning**
N	NCK-global
C	Channel-specific
A	Axis-specific

The parenthesis can be used in arithmetic expressions to define the order of execution for all operations and to invalidate the normal order of calculation.

For example:

```
IF(P10<50) AND ($AA_IM[X]>=17.5) GOTOF DEST
IF NOT R10 GOTOB START
```

When the CNC machine is turned on in flexible production, that is, FMC/FMS then we can talk about limited flexibility as a result of quick program editing which directly effect’s encumbered computer resources. Insufficient speed responds to quick changes in the production program in classic web, in correlation with the cell server FMC (computer) – DNC (computer) – CNC machine can be potentially recoverable with the use of RFID technology which is all about increasing the capabilities of subordinate computers within the system. Then the computers within the system gain meaning in correlation with previous partial autonomous control, they become anonymous and don’t depend on the server.

If parameters are added to the basic CNC program (in consideration with SINUMARIK control units there are R parameters as well) and variables which are related to interventions within the operation, which are read from the tag glued to the work piece, then the basic program becomes special, that is, the one that is associated with the specific work piece.

On Fig. 4. a block diagram intended for lathe processing is presented. The technological process is familiar, the sequence order is accurately specified, the product is the knowledge expert, and like that the core elements within the classic CAD-CAM technology for the lathe process are made.

Records read from the RFID reader are translated into a suitable form for merging with the basic CMC program (macro program). Structurally viewed the newly made file makes the R parameters that correspond with the correct parameters of procedures/cycles of the basic program, and variables of the sequence process which can take the values 0 or 1 or an NC sequence.

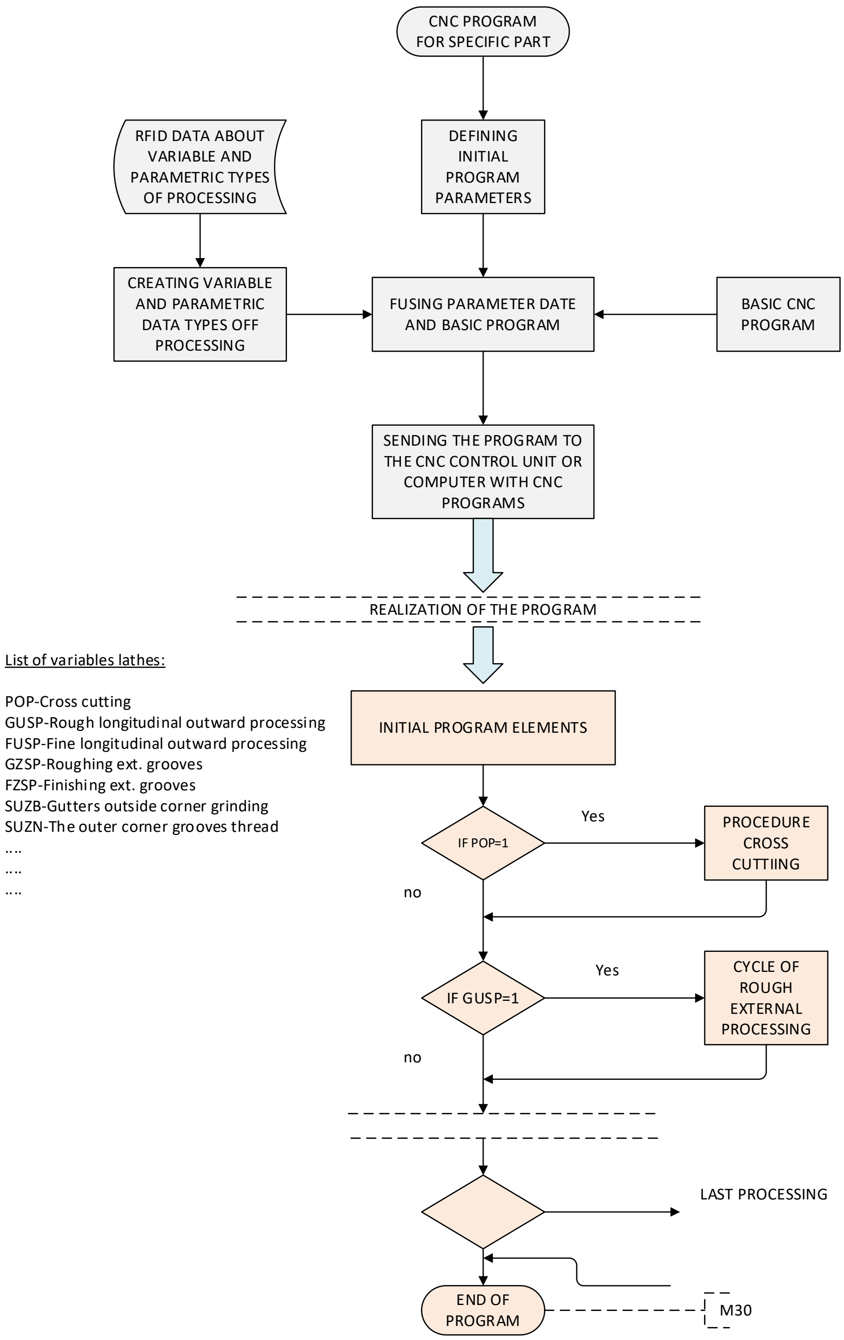

Figure 4: Flexible programming block diagram for processing on a lathe

If the variable value is 0 then the special program does not finish the process. This statement in the block diagram answers to the IF branch „no”. The opposite happens if the sequence variable takes 1, then a part of the program intended for that procedure/cycle is taken out. The CNC program is autonomous and the sequence order within the operation is confirmed on the basis of expert knowledge, that is, accurate definition. If the need should arise for a change in the sequence order in the operation (in cases when the user has experience and need for a different kind order), the user can access and edit the basic CNC program, which requires good G code programming and flexible programming knowledge.

Limiting factors submitted in the previous methodology is the memory capacity for the RFID tag. For these reasons we are allowed to modify in the previous methodology. That is, the RFID tag gains information about the identity of the work piece.

In the computer previously defined parameters are found which are then merged into a unique program.

In Fig. 5. a block diagram of this modified flexible programming is shown.

For CNC programs of great length the possibility of their creation via programming in CAD-CAM remains. RFID technology in this and similar cases of use can only be used for identifying the work piece, and through her, finding the program within the memory of the computer.

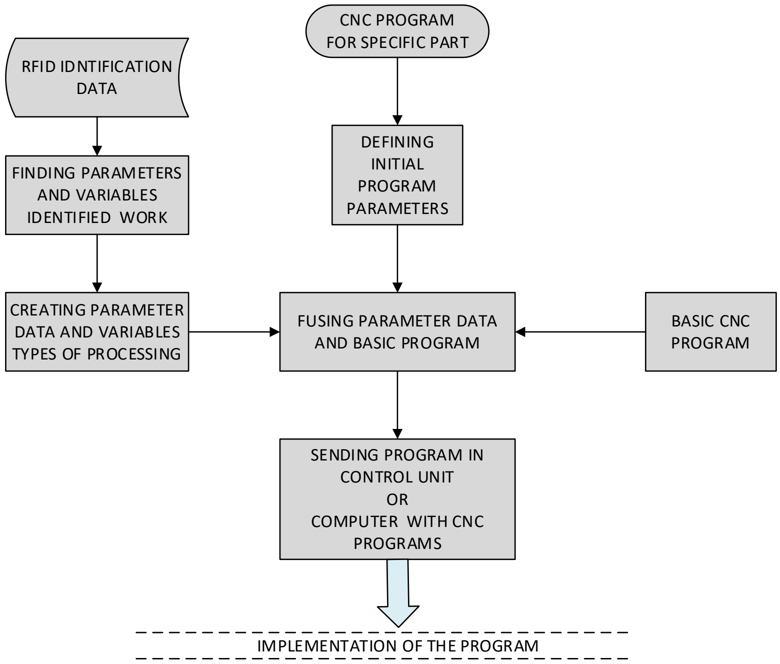

Figure 5: The modified block diagram of a flexible programming

4. INVESTIGATION RESULTS AND DEVELOPMENT DIRECTION

In the first experimental phase, we look at three groups of five different kinds for the lathe process, without the use of feedback in the program. The comparison is analyzed in two ways; G code and parametric programming. In the second phase, parametrically interpretable programs are analyzed with the use of RFID technology on the mill, whose algorithm structures contain the use of feedback. The programs that were tested were of 2½D geometry whose features are supported by the majority of control units.

The tested programs in the analysis (for both types of processing) result in the increase of efficiency in NC operations from the aspect of: the speed of the program change, realization of a bigger number of programs within the same time period, shorter program lengths, increased flexibility for a group of similar parts and relieving computer resources. The achieved results in the field of implementing MACRO programming with the use of RFID technology can be used to increase:

- the flexibility of the technological process,
- optimization and upgrade of the process (the technique and technology of the process, and
- increasing the level of study.

The results are theoretical and practical and have application in flexible manufacturing systems. With increased memory capacity on the transponders will enable the complete parameters for all, as well as longer programs, to be written and used in the technological process. The realization of these possibilities can lead us on the road to multiple readings of memory records and change its content of the transponder according to the possibilities given by the machine which is free and ready to take into itself the work piece during the production process. One of the directions also leads to the development of new control unit which aside from G code are capable of reading STEP-NC programs which can also be found on the transponder and be read and then realized in its form.

5. CONCLUSION

The use of flexible CNC programming gains full effect in cases when the CNC machine is a component of FMC/FMS and pieces of smaller dimensions with quick and frequent change of the production program. In these cases we can also talk about the character of adaptive control over the process, because the programs content is basic and the variables are those that define the realization of certain strategies of production, that is, the sequence. The values of the parameters give special attention to the technological production process and their value has a very important role in the very process. As previously stated, the computers within the web now have a completely new role; they have a specific degree of autonomy and are not subordinated to the server due to this. Based upon the aforementioned the opportunity to design new software packs arises, which can enable support for the flexible and effective process in the field of flexible production. The scientific goal of this work is research, development and implementation of RFID technology into the control systems of flexible manufactoring systems.

The realization of this basic goal, the upgrade of the process, is realized through the partial goals that will serve as a basis for: autotomatic identification of products based on RFID technology, planning the technological proces based upon the recording of tag and relieving the control system, that is, the localizatio of control.

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