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DYNAMICAL OPTIMIZATION OF THE TIP RELIEF PARAMETERS FOR AN INVOLUTE SPURS GEARING WITH IMPOSE CENTER BASED ON COMPUTER SIMULATION

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Abstract: *For the nonce of high precision's spurs gearing, the classical design algorithm does not ensure the necessary precision. In these cases, the computer simulation of the spurs gearings behavior and its dependence on the design, technological and operating parameters depict a viable choice. The paper analyzes the influence teeth shape (addendum modification coefficients) and the rotation speed on the tip relief parameters, based on computer simulation (original software builds on MatLab7 program), for an involute spurs gearing with imposed center with the goal of equal traction tensions at the level of the teeth base.*
Keywords: *tip relief parameters, static and dynamic hypothesis, addendum modification, rotation speed.*

1. INTRODUCTION

The simulation on computer of spurs gearings behavior represents an important work tool especially in the design phase of gears. Common design algorithms use formulae tables and easy to use diagrams that are not precise enough for high precision spurs gearing.

In the case of spurs gearing with imposed centre distance, the sum of addendum modifications results automatically, having two components: the sum of addendum modifications for obtaining the center distance and the sum of negative addendum modifications for obtaining the backlash [2], [4].

In [3] obtaining the equal bending carrying capacity means that the shape factors ratio must be equal with the static traction tensions from the base of the teeth ratio ($K_{F1}/K_{F2} = \sigma_{t\_sta1}/\sigma_{t\_sta2}$).

In [1] the simulation results for a base gearing (table1) in case of obtaining the same bending carrying capacity for both of the wheels teeth, it is shown that the distribution of addendum modifications coefficients is influenced in a main way by the input rotation speed of the gearing (table2).

Table 1: The base gearing

Parameter	Pinion	Wheel
number of teeth	21	41
module [mm]	4	
pressure angle [deg]	20	
face width [mm]	28	28
center distance [mm]	127	
contact ratio	1,4088	
backlash [mm]	0,1	
material	18MoCr10	
input load	800 Nm	

2. THEORETICAL BACKGROUNDS

The theoretical dynamic behavior of the spur gearing with involute profile can be improved by an accurate choice of the relief parameters. It is widely accepted that the level of the noise generated by the involute spur gearing is strongly related to the gear pair transmission error. In order to optimize the tip relief parameters of the teeth, the sum of the amplitudes of the first three Fourier series of the transmission error (static and dynamic) was established as objective function.

A computer program made-up in Matlab7 has been developed for predicting static and dynamic transmission errors and tooth forces, the dynamic factors, optimize the tip relief parameters of the teeth and establish the geometry of the generating rack corresponding to the tip relief tooth.

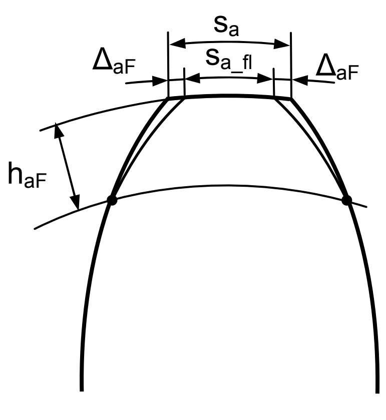

Fig.1. The tip relief parameters

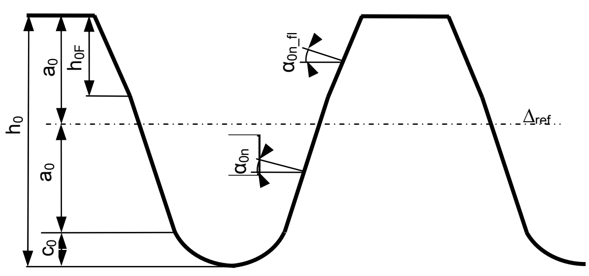

Fig.2. The geometry of the generating rack corresponding to the tip relief tooth

3. THE OPTIMIZING RESULTS

The optimization was made for 7 gearings, each having the same bending carrying capacity for both of the wheels teeth, static and dynamic point of view. The results of the simulations are presented in table 2.

Table2: Results of the simulations

Gearing		*I*	*II*	*III*	*IV*
Rotation speed [rpm]		750	1000	1500	2500
Sum of addendum modif.		0.77681627100092			
Pin's addendum modification coeff.	static	0,43009			
	dynamic	0.22161425148675	0.23794372264893	0.26515950791923	0.32503423551390
Mesh frequency [Hz]		262.5	350	525	875
Results of optimization					
Initial objective function	static	0.01785245867613	0.01781469941715	0.01775852349466	0.01766482161315
	dynamic	0.01813578929454	0.01822462818265	0.01851339715211	0.01984743920137
Minimum of objective function	static	0.00102723494223	0.00105302935637	0.00101808171573	0.00094852939914
	dynamic	0.00103881172493	0.00107741196817	0.00106343490459	0.00129755432707
Reduction in objective function	static	17.3791388339794	16.9175714897073	17.44312192261161	18.62337807258911
	dynamic	17.4582061978190	16.9151900304252	17.40905538477479	15.29603715798736
Δ_{aF_pin} [mm]	static	0.05700911488695	0.05956411228797	0.06245465204128	0.05082125265088
	dynamic	0.05691665309875	0.05942649010222	0.06235055933674	0.05005839626861
$\Delta^*_{aF\_pin}$	static	0.01425227872174	0.01489102807199	0.01561366301032	0.01270531316272
	dynamic	0.01422916327469	0.01485662252556	0.01558763983418	0.01251459906715
h_{aF_pin} [mm]	static	2.38066235904812	2.34836150207119	2.21119601985480	2.49432780472223
	dynamic	2.38778256744389	2.32270869949413	2.19888406611609	2.48084451484941
$h^*_{aF\_pin}$	static	0.59516558976203	0.58709037551780	0.55279900496370	0.62358195118056
	dynamic	0.59694564186097	0.58067717487353	0.54972101652902	0.62021112871235
Δ_{aF_roa} [mm]	static	0.05622544870824	0.05837704860540	0.06134052123072	0.05358359051654
	dynamic	0.05613860061405	0.05881671855021	0.06354926916481	0.05357395734882
$\Delta^*_{aF\_roa}$	static	0.01405636217706	0.01459426215135	0.01576992697287	0.01339589762914
	dynamic	0.01403465015351	0.01470417963755	0.01588731729120	0.01339348933721
h_{aF_roa} [mm]	static	2.21013707451408	2.10991865820143	2.05553805896023	2.32963162985738
	dynamic	2.20826612560748	2.12614982858670	2.05649949847600	2.37038011342049
$h^*_{aF\_roa}$	static	0.55253426862852	0.52747966455036	0.51388451474006	0.58240790746435
	dynamic	0.55206653140187	0.53153745714668	0.51412487461900	0.59259502835512
Geometrical parameters of the generating racks					
$\alpha_{on\_fl\_pin}$ [grd]	static	21.5367151316965	21.6309669043858	21.8255647039293	21.33030582711576
	dynamic	21.5294814683728	21.6461326791890	21.8331889033611	21.31837480107073
$x_{\_fl\_pin}$	static	0.24449189187407	0.26232657293015	0.29400139224496	0.34176850553876
	dynamic	0.24428494767098	0.26294204241190	0.29432403501655	0.34179212096406
h_{0F_pin} [mm]	static	2.96036720811746	2.96363337040670	2.91611431654612	3.14266392912046
	dynamic	2.96489938494253	2.94665564704131	2.90822529289388	3.13211142679216
$\alpha_{on\_fl\_roa}$ [grd]	static	21.5779459007768	21.7124182077983	21.8391208873469	21.40957847236482
	dynamic	21.5769347092459	21.7115832140903	21.9022740957161	21.38442263541363
$x_{\_fl\_roa}$	static	0.57923628006633	0.56684994202167	0.54310673904867	0.47317127388384
	dynamic	0.57925085997413	0.56656273826433	0.54410719336151	0.47222743801440
h_{0F_roa} [mm]	static	3.03654186570691	2.96541843097957	2.91596891520133	3.00076185329191
	dynamic	3.03500305586161	2.97729297295662	2.92630573543410	3.02858743447983

Table2: Results of the simulations (continuation)

Gearing		*V*	*VI*	*VII*	
Rotation speed [rpm]		5000	7500	10000	
Sum of addendum modif.		0.77681627100092			
Pin's addendum modification coeff.	static	0,43009			
	dynamic	0.36702430421665	0.39735046494642	0.42145587475726	
Mesh frequency [Hz]		1750	2625	3500	
Results of optimization					
Initial objective function	static	0.01809759291752	0.01807941310006	0.01807237722778	
	dynamic	0.03596215718214	0.01959631667231	0.02476259554170	
Minimum of objective function	static	0.00105733680109	0.00110345475546	0.00102680669719	
	dynamic	0.00313731839271	0.00122890609462	0.00060794581199	
Reduction in objective function	static	17.1162045044335	16.3843719106753	17.6005642320386	
	dynamic	11.4627056232810	15.9461465429297	40.7315833966256	
Δ_{aF_pin} [mm]	static	0.05703695446077	0.05223410424487	0.05769024558002	
	dynamic	0.05632599174805	0.05188571598373	0.05504355912251	
$\Delta^*_{aF\_pin}$	static	0.01425923861519	0.01305852606122	0.01442256139501	
	dynamic	0.01408149793701	0.01297142899593	0.01376088978063	
h_{aF_pin} [mm]	static	2.18276626975036	2.40540453533003	2.10766807334904	
	dynamic	2.15871254684257	2.39297208032602	2.26446477103775	
$h^*_{aF\_pin}$	static	0.54569156743759	0.60135113383251	0.52691701833726	
	dynamic	0.53967813671064	0.59824302008150	0.56611619275944	
Δ_{aF_roa} [mm]	static	0.06133761768479	0.05569628798128	0.06434038520185	
	dynamic	0.06231881357771	0.05496957471697	0.06024506882602	
$\Delta^*_{aF\_roa}$	static	0.01533440442120	0.01392407199532	0.01608509630046	
	dynamic	0.01557970339443	0.01374239367924	0.01506126720651	
h_{aF_roa} [mm]	static	2.08419295418565	2.15294147035376	2.04975605860280	
	dynamic	2.30320986354992	2.25234357749865	2.10684676195626	
$h^*_{aF\_roa}$	static	0.52104823854641	0.53823536758844	0.51243901465070	
	dynamic	0.57580246588748	0.56308589437466	0.52671169048906	
Geometrical parameters of the generating racks					
$\alpha_{on\_fl\_pin}$ [grd]	static	21.7199751024862	21.4342762632239	21.8153673975275	
	dynamic	21.7187630890659	21.4327106281547	21.6117112274214	
$x_{\_fl\_pin}$	static	0.39236143552086	0.41510677086636	0.44792440067150	
	dynamic	0.39271695002529	0.41525125028520	0.44281961971824	
h_{0F_pin} [mm]	static	3.01396342049506	3.17759220959681	3.04441891307600	
	dynamic	2.99753915966026	3.16890912743309	3.12925973149822	
$\alpha_{on\_fl\_roa}$ [grd]	static	21.7921587828949	21.5728465376477	21.8965499368911	
	dynamic	21.6437268542577	21.4826911918939	21.7303307829772	
$x_{\_fl\_roa}$	static	0.44182551701723	0.40714635565580	0.39078171400165	
	dynamic	0.43565403082775	0.40412204743501	0.38685491395678	
h_{0F_roa} [mm]	static	2.82688642704531	2.81947135367540	2.76244234643984	
	dynamic	2.97248061655580	2.88380267177807	2.78283250033869	

4. DISCUSSIONS

Figures 3, 4, 5 and 6 show the variations of the optimum relief depths and heights of the pins and the wheels depending on rotation speed and implicit of the addendum modification coefficients in the static and dynamic hypothesis (table 2).

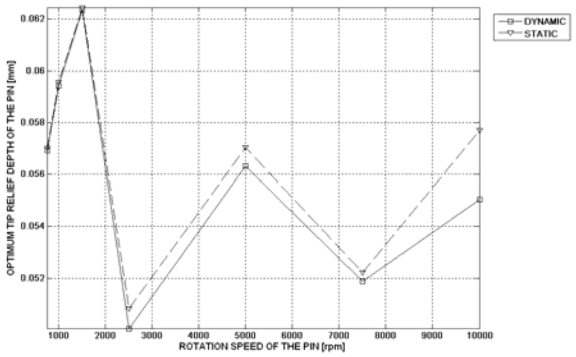

Fig.3. Variations of the pin static and dynamic optimum tip relief depths

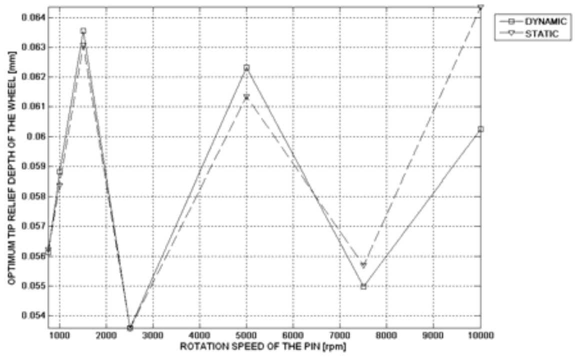

Fig.4. Variations of the wheel static and dynamic optimum tip relief depths

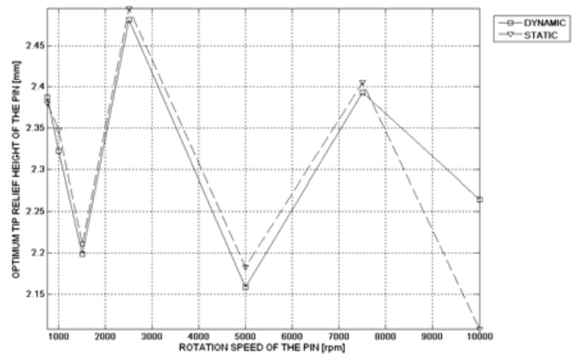

Fig.5. Variations of the pin static and dynamic optimum tip relief heights

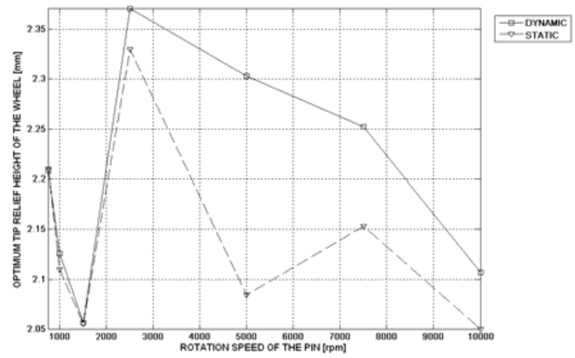

Fig.6. Variations of the wheel static and dynamic optimum tip relief heights

Analyzing the curves of the variations in static hypothesis it is clear that the optimum relief heights and depths depend on the form of the teeth, that is the value of the coefficients of addendum modifications without a proportional dependency.

In the case of 750, 1000 and 1500 rpm the values of the optimums relief heights and depths, static and dynamic, have close values, but for higher speed, the differences are bigger.

Figures 7 and 8 show the variations of the optimum relief depths and heights of the pins and the wheels in the dynamic hypothesis.

In case of most of the gears the optimum relief depths of the pin teeth, have lower values than those of the wheel, but as regards the optimum relief heights, the pin values are generally higher.

Figure 9 shows that the values of the optimum coefficients of the pin and wheel relief depths match the recommendations of the Romanian Standards (STAS) and ISO.

As regards the optimum coefficients of the pin and wheel relief heights (figure 10), the values are close to the limit established by ISO, and exceed the limit given by STAS.

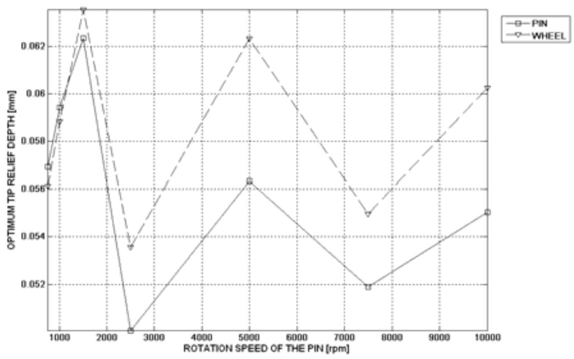

Fig.7. Variations of the pin and wheel dynamic optimum tip relief depths

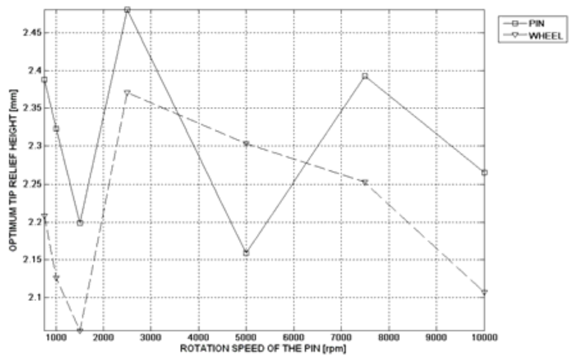

Fig.8. Variations of the pin and wheel dynamic optimum tip relief heights

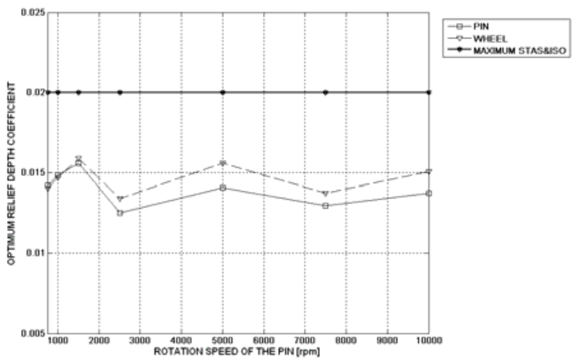

Fig.9. Variations of the pin's and wheel's dynamic optimum tip relief depth coefficients

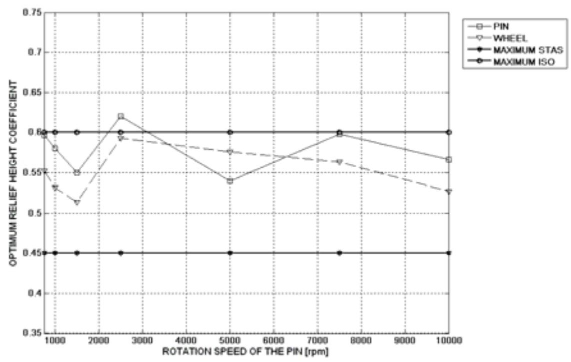

Fig.10. Variations of the pin's and wheel's dynamic optimum tip relief height coefficients

5. CONCLUSION

The conclusions show that establishing the relief parameters in order to improve the vibro-acoustic behavior is a problem of optimization.

For low rotation speed, a static optimization of the tip relief parameters can be done with sufficient precision.

6. REFERENCES

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