Operating properties of photopolymer stamps for hot foil stamping

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Hot foil stamping of printed products is very popular in postpress processes. Use of photopolymer materials for stamps producing is a well known process. This work provides operating properties (hardness, deformation and thermophysical properties, wear resistance) research of novel photopolymer materials for direct laser engraving of stamps for hot foil stamping. Research results comparison with requirements to photopolymer materials for printing plates and stamps made it possible to provide a conclusion about suitability of the researched materials for stamps producing.

Keywords: photopolymer stamps, physico-mechanical properties, direct laser engraving.

Introduction

The mass use of hot foil stamping for printed production finishing predetermines search of process simplification methods, its productivity and quality increase, improvement of ecological and economical aspects. In this case photopolymer stamps are perspective due to their low cost, simplicity of producing and technical properties [1]. However such stamps have a number of shortcomings: low heat-resistance and wearproofness, utilizing of photomaterials and chemical solutions which result in reproduction and operating indexes worsening [2,3]. Therefore a problem of technological processes and photopolymer stamps composition improvement remains actual.

Patent search analysis, literary data and practical researches have shown the advantages of direct laser engraving as the image forming method on a photopolymer printing plate due to simplicity of technological process, quality improvement of printing plates, removal of environment harmfull operations [2-5].

The main tasks of the research were: the development of a range of photopolymer compositions for stamps producing by means of direct laser engraving and their operating properties definition.

Materials and methods

Due to the literary and previous researches the following components for liquid photopolymer compositions have been choosen: basic oligomer component – urethane acrylate pre-polymer (UA 2100T and UA based on isophorone), monomer – tetraethylene glycol diacrylate (TEGDA), photoinitiator system for superficial and volume polymerization – benzophenone and alpha,alpha-dimetoxy-alpha-phenylacetophenone (Irgacure 651), two modifying admixtures for physico-mechanical properties improvement. Compositions contain 56 to 61% of urethane acrylate pre-polymer, 20% of tetraethylene glycol diacrylate, 4% of photoinitator system, 10% of modifying additive No.1 and 0 to 10% of modifying additive No.2. As a result we've got 6 compositions with the percentage of components shown in Table 1.

The photopolymer composition was cured with UV light on a steel plate (0,3 mm thick) for dimension stabilization and better operating properties. The total thickness of material was 1,3 mm.

A standard material for comparison with the novel compositions also have been choosen. It is a photopolymer plate Rigilon MX 145 (TOK, Japan) due to the fact of mass use for photochemical producing of polymer stamps for hot foil stamping. The main components of Rigilon MX 145 plates are urethane and amide acrylates.

The hardness determination of photopolymer stamps was conducted in Shore A points.

The research of deformation properties of photopolymer stamps have been examined both under the variable loading (up to 4,31 MPa) and permanent loading

Table 1. Composition of the photopolymer material

Composition	Percentage of components, %					
	UA 2100T	UA based on isophorone	TEGDA	Photoinitiator system	Additive No.1	Additive No.2
Sample 1	66		20	4	10	
Sample 2		66	20	4	10	
Sample 3	56		20	4	10	10
Sample 4		56	20	4	10	10
Sample 5	61		20	4	10	5
Sample 6		61	20	4	10	5

(2 MPa) on IZV-1 device. In the first case the loading was increasing and then decreasing with step 0,49 MPa and in the second case the deformation indexes were taken in 5sec, 15 sec, 30 sec, 1 min, 2 min, 5 min, 10 min, 20 min, 30 min after loading and the same after loading removal.

Friction tests were carried out on a tribotester with the square friction head under normal load 0,5 N, number of cycles n = 6000. All the tests were conducted at the temperature +20-21°C and humidity 60% according to the state regulations.

Thermomechanical tests have been carried out on a device which was constructed in Ukrainian Academy of Printing and consists of the heating module, device of heating speed adjusting and digital indicator of thickness change. Total load was 0,15 MPa and the normal heating speed 2°C/min.

Results and discussion

On the basis of experiment data the diagram of material hardness and compression, graphs of relative deformation dependance on the time of loading and tem- perature have been generated.

The samples hardness comparison is shown on Fig. 1. The measured hardness of Rigilon MX 145 material is 89,2 points Shore A. Hardness of the designed samples

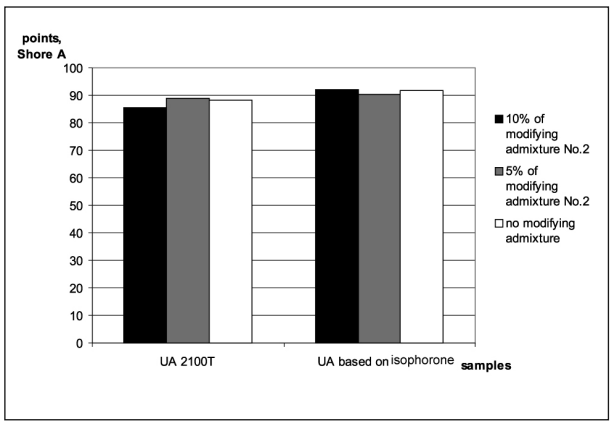

Fig.1. Indexes of material hardness

varies within the limits of 85-92 points Shore A. Materials on UA isophorone have slightly higher hardness, than materials on UA 2100T. Additives also affect the hardness of these materials: 0 to 5% of additive No2 provides the closest rates (Samples 2, 4, 6) to the standard material.

Figure 2 depicts the deformation and relaxation processes under the variable loading (0-4,31 MPa) for the designed samples and standard material. Deformation characteristics of polymer materials were evaluated by tension-deformation curves (σ-ε) in the process of loading and unloading of these materials. It can be seen that compression and recovery curves do not match, it means samples are not fully recovered. Samples 2 and 5 have residual deformation (both 1,1%). In terms of thermodynamics work A that is spent on deformation comes back while elastic deformation and is partly converted into heat Q while plastic deformation. That's why equation $A_{compression}=A_{recovery}+ Q$ is fair for this kind of deformation. This means that in the process "compression-recovery" part of work is irreversibly lost [6,7].

Samples 1 and 2 have the highest deformation of 21% under the maximum load 4,3 MPa. Maximum deformation of samples 3 and 4 with 10% of additive No.2 is 13,22% and 13,66 %. While unloading they relax completely that indicates the plasticity and elasticity of the material. Fig. 2 also depicts that the lowest rate of deformation have samples with 5% of additive No.2: 8,77% for sample 5 and 5% for sample 6.

For the study of deformation properties of photopolymer materials under permanent load (1,87 MPa) the relative deformation in determined time period has been calculated. Fig. 3 depicts the kinetics of material deformation change, where section to the loading time 1800 sec (30 min) corresponds to the change in relative deformation under load, and the section from 1800 sec to 3600 sec describes the deformation recovery. Deformation develops quickly at the first minutes of loading and is described by the Hooke law. Such deformation is called elastic and relaxes immediately after removing the load. Plastic deformation develops next and has longer relaxation time, it might not relax totally and remains as residual deformation [8].

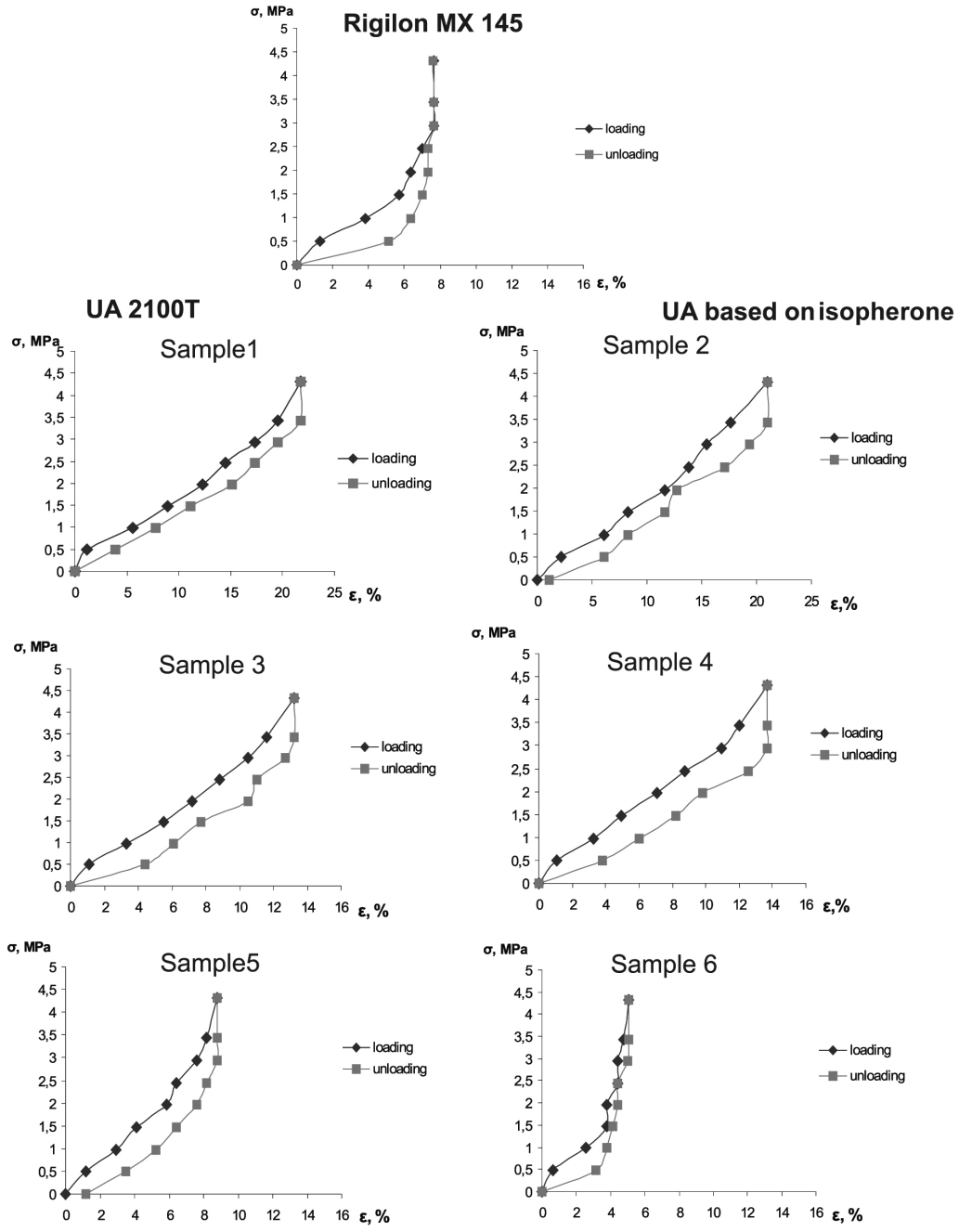

Fig. 2. The relative deformation change at compression and unloading of samples

Samples 1, 3 and 5 on the basis of UA 2100T have higher deformation indexes than samples 2, 4, 6 on the basis of UA isophorone. Samples 2 and 6 with 0-5% of modification additive No.2 have the lowest deformation characteristics which are the best in relation to standard sample (Fig. 3).

Explanation of deformation data is that compressed flexible UA chains due to their structure, transformation and interaction with TEGDA come back to their original state after removing the load.

Deformations distribution is calculated using data from Fig.3 (Table 2).

Stamps are characterized by a favorable deformations division which provides better printing contact and less time on setup.

Figures 4 and 5 depict compositions wear resistance. Mass wear and gradient of wear speed have been calculated on the basis of measured mass change values. The initial friction is characterised by rapid mass loss of the polymer stamp which then slows down. This effect can

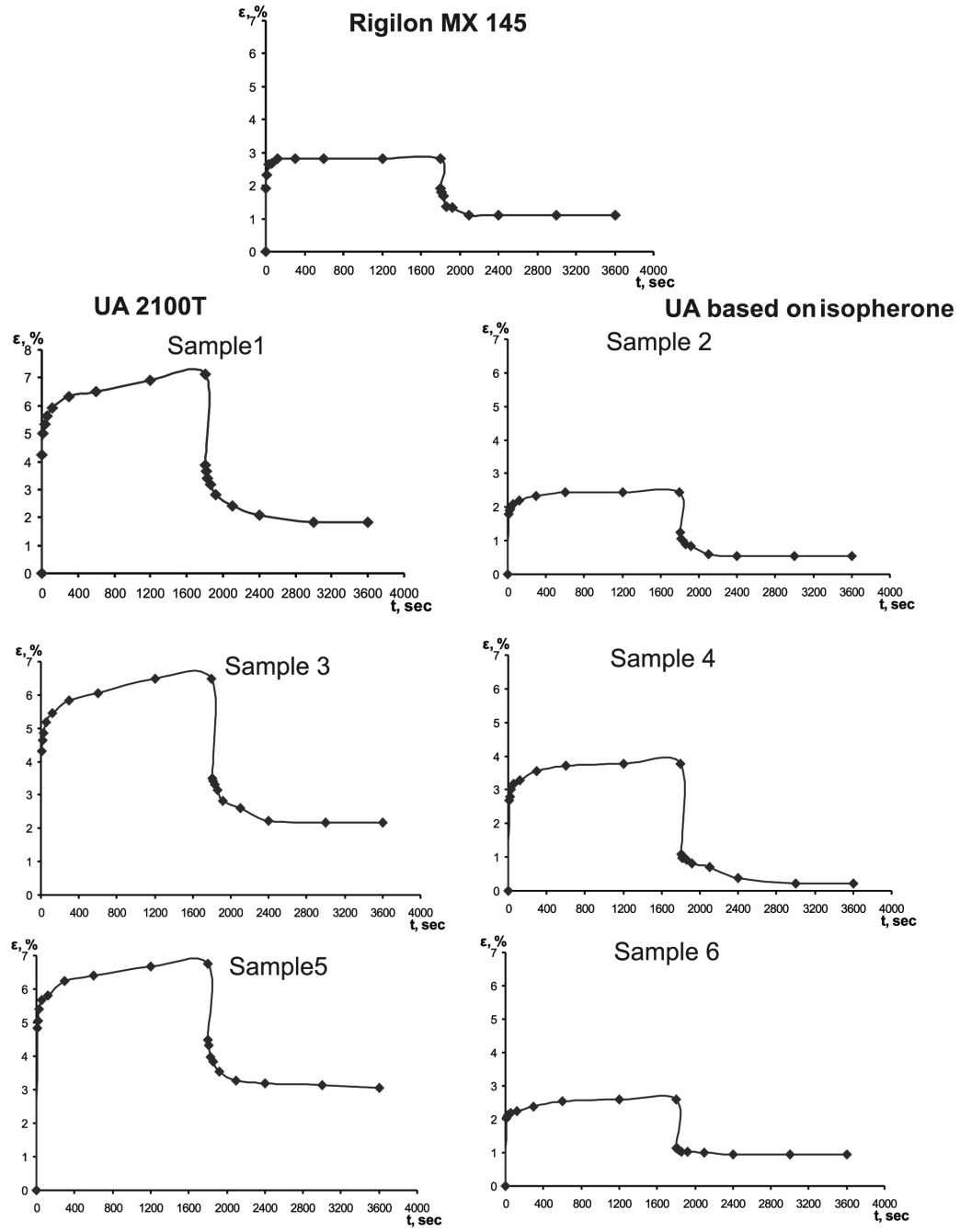

Fig. 3. Deformation kinetics under permanent load.

Table 2. Deformations distribution under under permanent load (1,87 MPa)

Deformation	Standard sample (Rigilon MX 145)	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Elastic deformation, %	0,91	3,24	1,19	2,97	2,69	2,27	1,45
Plastic deformation, %	0,81	2,07	0,71	1,35	0,86	1,42	0,21
Residual deformation, %	1,09	1,80	0,54	2,17	0,21	3,06	0,94
Total deformation, %	2,81	7,12	2,44	6,49	3,76	6,75	2,60

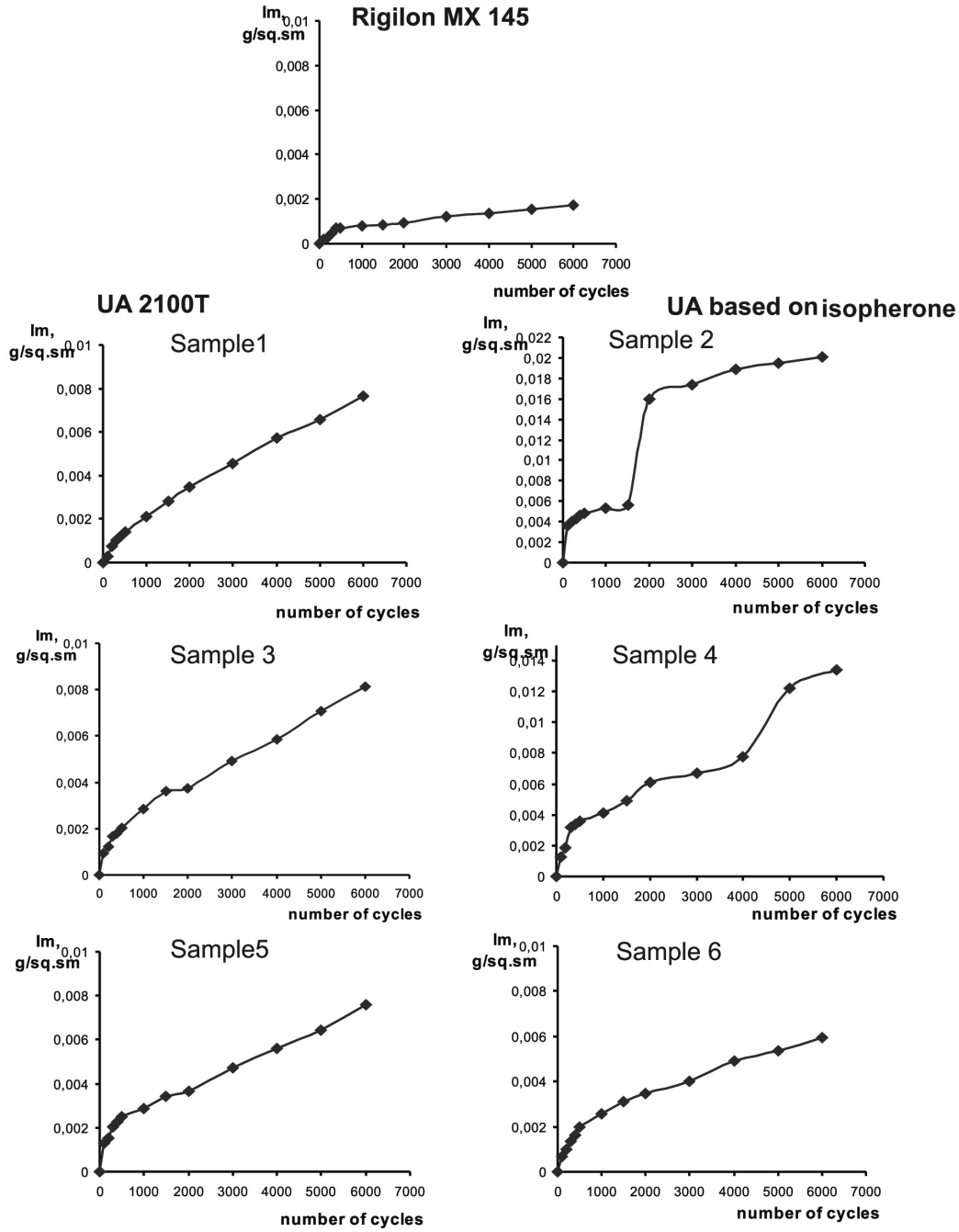

Fig. 4. The specific wear by weight dependence of the number of friction cycles

be explained by the grinding process of surfaces. Gradient of wear speed is very high at early stages of wear then decreases and stabilizes (Fig. 5). This shows that there are several stages of wear (due to the typology of the photopolymer material structure).

The highest wear rates have samples 2 and 4 on the basis of UA isophorone (mass wear up to $2x10^{-2}$ gr/sq.sm after 6000 cycles of wear).

Slightly lower indexes of mass loss have samples 1, 3, 5 based on UA 2100T, their wear resistance doesn't depend much on the content of additive no.2. The highest wear speed indexes have sample 1 (without additive no.2) and sample 3 (with 10% of additive no.2).

Among the tested materials sample 6 showed the highest wear resistance: the mass wear ranged from $6,86x10^{-4}$ to $5,9x10^{-3}$ gr/sq.sm and gradient of wear speed ranged from $1,2x10^{-4}$ to $1,7x10^{-5}$. These data match the best with the standard material Rigilon MX 145: its mass wear ranges from $6,83x10^{-4}$ to $1,7x10^{-3}$ gr/sq.sm and gradient of wear speed ranges from $2,8x10^{-5}$ to $5,8x10^{-6}$.

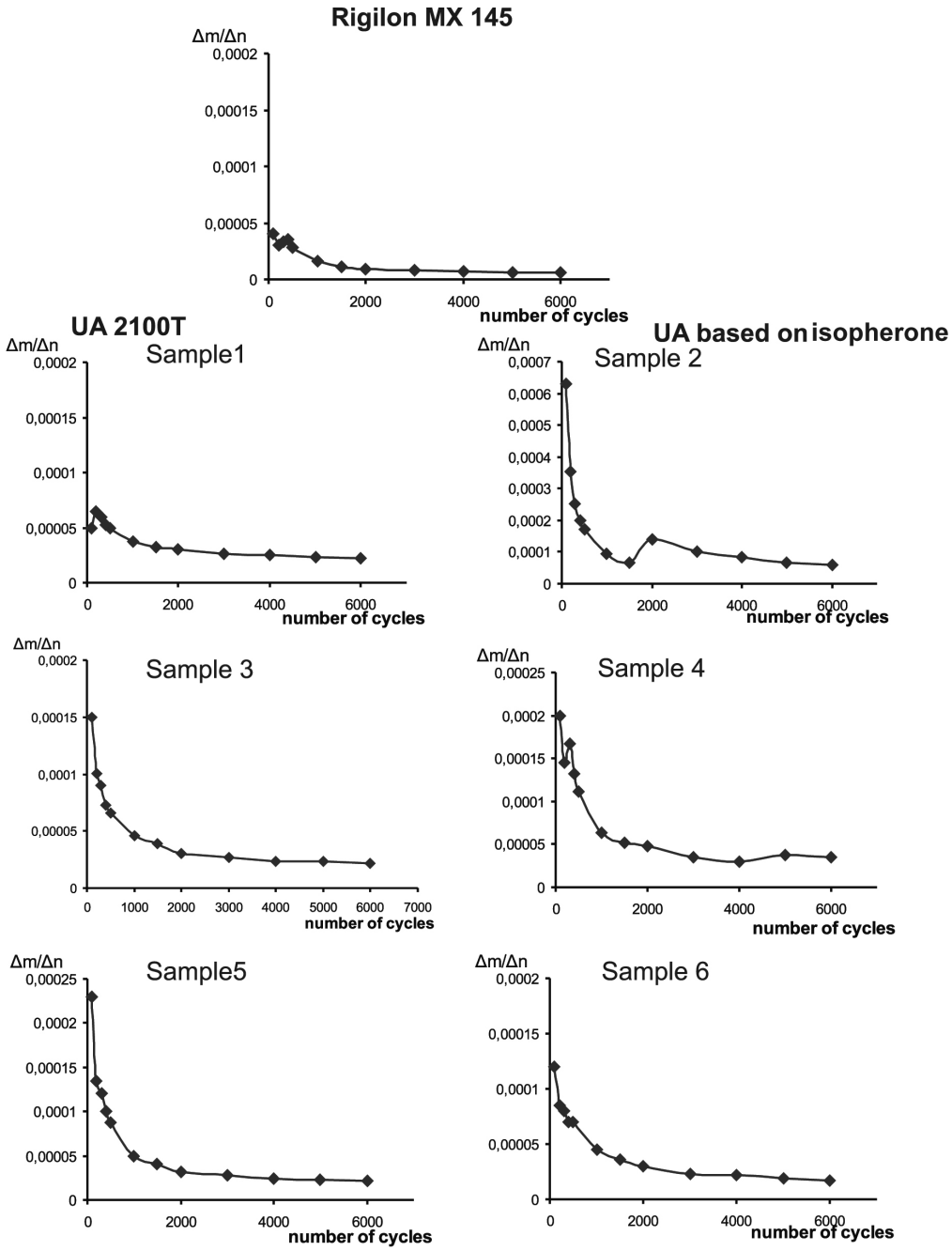

Fig. 5. The gradient of wear speed dependence of the number of friction cycles

On the basis of thermomechanical tests of polymer materials relative deformation under the temperature action has been calculated (Fig.6). Initially thermomechanical curve rises sharply and at +40-85°C (for different materials) deformation growth stabilizes and remains insignificant. This area corresponds to elastic state of samples in which the segmental mobility of macromolecules is activated, internal tensions appear and resist deformation [8].

The sample material is characterized by small deformations (5,9%) at heating temperature up to +150°C. That indicates fully sewn material structure and high thermal stability in the working range.

Materials based on UA 2100T are characterized by a small deformation but elastic state appears for sample 1 at +58°C, sample 3 at +78°C, sample 5 at +72°C that is too low for stamps for hot embossing.

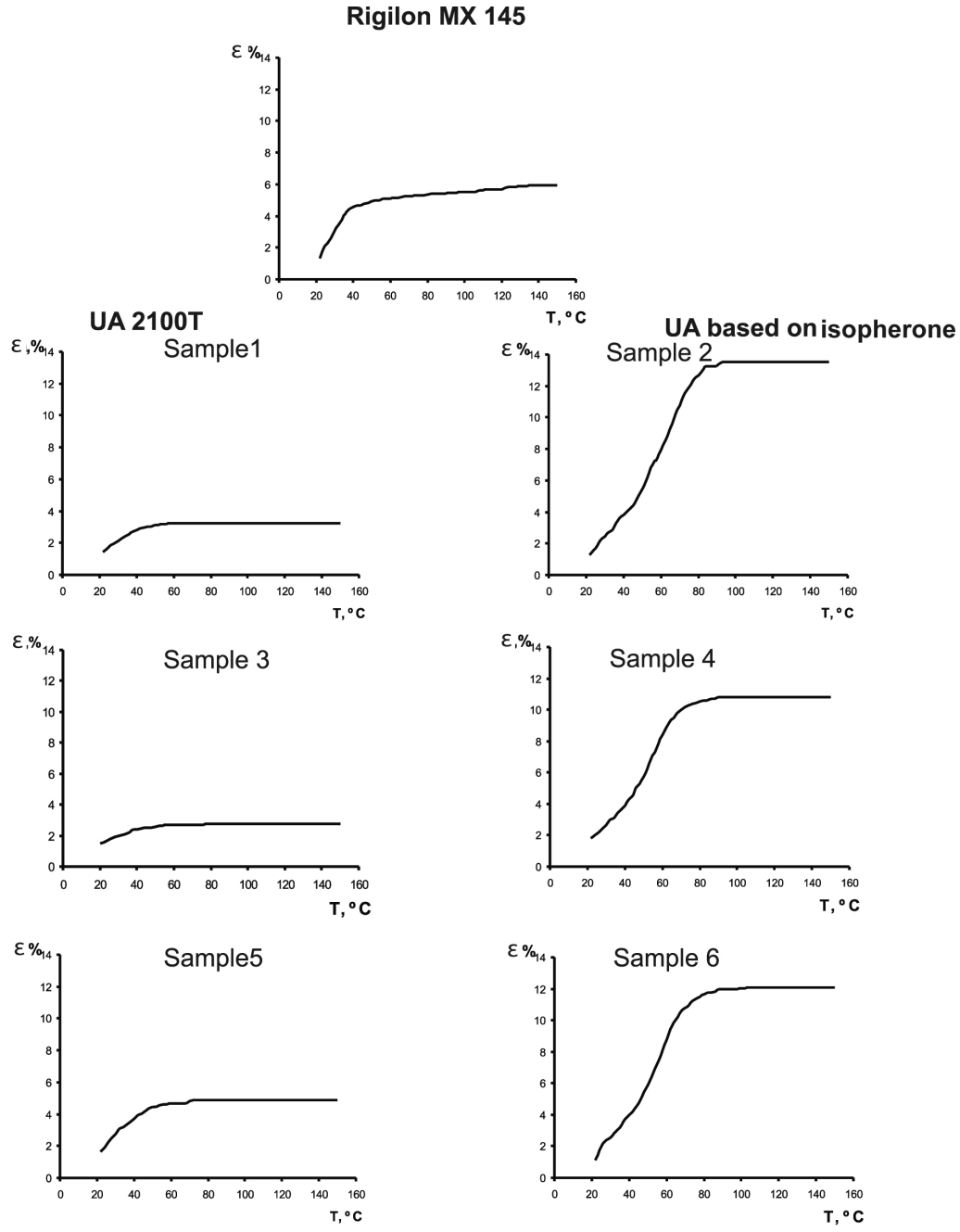

Fig. 6. Thermomechanical curves of polymer materials

Materials based on UA isophorone are characterized by higher deformations in comparison with the standard material. Elastic state appears at much higher temperatures than in the UA 2100T: sample 2 at +94° C, sample 4 at +90°C, sample 6 at +104°C.

Conclusions

Deformation and thermophysical properties, wear resistance and hardness of new photopolymer materials on the basis of urethane acrylates for the direct laser engraving are an interesting source of information about the exploitation processes of stamps for hot foil stamping. Research results comparison with requirements to photopolymer material for printing plates and stamps made it possible to provide a conclusion about suitability of the researched materials for stamps producing. Among number of researched materials sample 6 is the most suitable for this purpose on all aspects.

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