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## Message from the Editor-in-Chief

I am happy to share that The Online Journal of Science & Technology (TOJSAT) has been published third issue in 2011. The first and the second issues covered the selected papers from the conference which was entitled as International Science & Technology Conference, 2010. These issues reflected how our journal works to share and diffuse contemporary science & technology practices from various fields to the academic platform.

As you know science and technology issues are very important fields to develop our academic and scientific development. This journal aims to improve quality of scientific and technological proceedings and articles.

As the main mission of the journal is to promote knowledge sharing within professional agenda based on multi-disciplinary approach, the third issue also covered various studies from different fields.

I would like to thank to editorial board, reviewers and the researchers for their valuable contributions to the journal and this issue.

Furthermore, I am pleased to announce that further issues will also cover the selected papers from International Science and Technology Conference, 2011 besides the submitted papers to the journal. Once again, I am happy to publish third issue with interesting and valuable researches in order to share with academic world.

**July 01, 2011**

**Prof. Dr. Aytekin İŞMAN**

Editor-in-Chief of TOJSAT

## Message from the Editor

Now, it is time to read the third issue of Tojsat journal. It is a newly established and fast developing journal which covers all subject areas of Science and Technology.

In this issue of journal, paper entitled as Integrated Watershed Management: Socio-Economic Perspective by Mehmet KARPUZCU, Şermin DELİPINAR , Numerical Simulating for Rain-Wind induced Vibration of Inclined by Xing MA, Removal of Fine Particles from Wastewater using Induced Air Flotation by Tuba TAŞDEMİR, Adem TAŞDEMİR , Yaprak GEÇGEL, Truck Chassis Structural Thickness Optimization with the Help of Finite Element Technique by I. Kutay YILMAZÇOBAN, Yaşar KAHRAMAN, and Machinability of Magnesium and its Alloys by Birol AKYUZ are published.

Next issue of the journal will cover the selected papers presented in International Science and Technology Conference, 2010.

**July 01, 2011**

Prof. Dr. M. Şahin DÜNDAR

Editor, TOJSAT

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# INTEGRATED WATERSHED MANAGEMENT: SOCIO-ECONOMIC PERSPECTIVE

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**Abstract:** Integrated watershed management (IWM) is becoming increasingly important in such a country where the economy depends predominately on agriculture, but there are also fast-growing urban populations that depend on water and food supplies on an unprecedented scale and attention is shifting to overall socio-economic benefit along with better water and soil conservation. The ever-increasing pressure on the natural resources is further increased the intensity by the even faster economic growth the country has witnessed in the past decades. Unprecedented economic activities in areas such as agriculture, industry, power, and communication, are affecting land-use patterns in many ways.
The aim of this paper is to emphasize the importance of the effective IWM, to point out the relations between its components and to realize on beneficiaries in any watershed. In particular, social, economic, environmental, and resource systems are all considered in order to improve the applicability of IWM approach.
This paper presents that watershed management integrates various aspects of forestry, agriculture, ecology, soils,
water use and other sciences to provide guidelines for the choosing appropriate IWM alternatives within the social and economic context. Addressing social and economic aspects is an essential part of evaluating the effects of IWM.

**Keywords:** IVM, social, economic, environmental

## INTRODUCTION

IWM is becoming increasingly important concept in all over the world and attention is shifting to overall socio-economic welfare along with better water and soil conservation. Global population is continuing to grow rapidly. The ever-increasing pressure on the natural resources is further increased the intensity by the even faster economic growth, the country has witnessed in the past decades. Unprecedented economic activity in areas such as agriculture, industry, power, and communication, is affecting land-use patterns in many ways.

Major increasingly challenging problems of socio-economic development in watersheds, e.g. scarcity of natural resources and environmental deterioration, have arisen. IWM is a useful tool for dealing with these issues and maintaining sustainable development at the watershed scale. According to Bouwer (2000), IWM is such a holistic approach which requires not only supply management, but also demand management (water conservation, transfer of water to uses with higher economic returns, etc.), water quality management, recycling and reuse of water, economics, public involvement, public health, environmental and ecological aspects, socio-cultural aspects, water storage (including long-term storage), conjunctive use of surface water and groundwater, water pollution control, flexibility, regional approaches, weather modification, sustainability, etc.

Application of the effective IWM approach within a comprehensive public involvement program on watersheds systems maintains a balance of protection of watershed's natural resources and economic growth opportunities, provides a framework for long-term stream sustainability, and fullfils all the requirements of beneficiaries as equitable.

IWM involves the management of the socio-economic, human-institutional, and biophysical interrelationships between soil, water, and land-use, and the connection between upland and downstream areas (Wang et al, 2005).

German Agency for Technical Cooperation (GTZ) defines IWM as the process of organizing land use and the use of other resources in a watershed in order to provide sustainable desired services to the people without adversely affecting soil and water resources. This definition recognizes the interrelationships among land use, soil and water, the linkages between uplands and downstream areas, and the numerous types of stakeholders (Kotru, 2005).

Liu and others (2007) stated that a watershed management system is usually divided into social, economic, environmental, and resource components. The relationships among these components complicated at the watershed scale (Fig. 1).

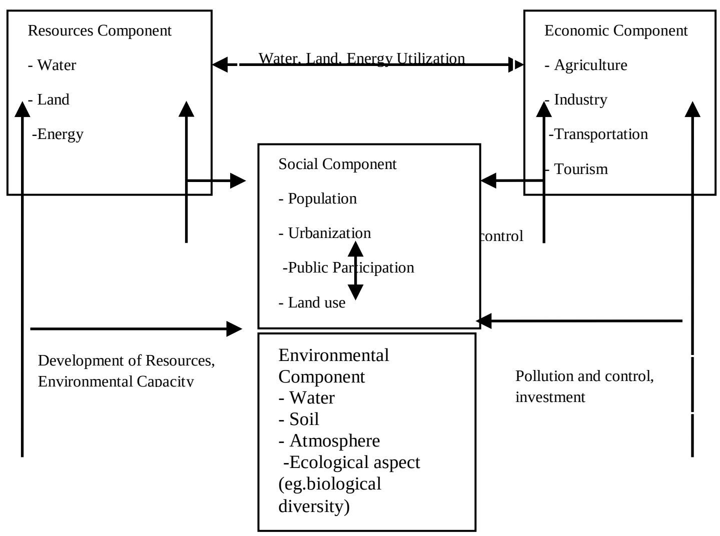


**Figure1.**The Components of Watershed

When the economic, social, environmental, and resource components of watershed are analyzed, the potential development of economic and social components, and of existing or potential problems in environmental and resource components are focused on. These components have mutual interactions, interrelated and interdependent each other, like the links of a chain or the spokes of a wheel, as seen in fig.1. Damage to any one watershed component runs the risk of damage to all. For example in the case of environmental pollution, the scarcity of water resources as accepted key problems of watershed, driving forces of watersheds components are the financial budget and national policies, which can greatly influence as essential elements changing in the watershed. Social, environmental, and economic components are associated with the sustainability goal. Effective indicators of sustainability provide a balanced view of environmental, social, and economic conditions at the scale of interest (community, ecoregion, basin, county, etc.). This is particularly attractive because of our social and economic success that stems from fertile agricultural valleys and productive forests, abundant fishery resources, and a diverse array of recreational opportunities. The economic policies, which are including raising the price of water in urban areas, the development of watersaving agriculture, the implementation of cleaner production methods, and the establishment of a subsidiary system for developing water saving techniques, could be adopted to reduce water resource utilization and, hence, to reduce wastewater discharge. The goal of these policies would be to protect water quality and reduce the financial burden of environmental investment in the watershed.

## Integrated Watershed Management (IWM)

IWM is a process of conservation, development and optimal utilisation of the available natural resources in a watershed on a sustained basis. It is a process with a multidisciplinary approach with people in the watershed as chief functionaries (decision makers and main actors) in the process(Winnegge, 2005). The concept of IWM are increasingly important in the case of shortages of land or water or of both need to be addressed, since it is the only approach capable of balancing growing demand for a limited resource with a sustainable resource base.

The Technical Advisory Committee of Global Water Partnership has adopted the following definition: IWM is a process, which promotes the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (Gooch, and Stålnacke, 2003).

The distinction between “integrated” and “traditional” management of water, river basins or water resources to a large extent relies on the scope and sphere of operation of the two. Whereas traditional one is typically sector-oriented (water supply, irrigation, hydropower, etc.) and focused on satisfying the perceived demands within each sector, the integrated one attempts to take a cross-sectoral approach and focus as much on management of the water or in terms of water resource management on the demand, supply, and use of water (Gooch and Stålnacke, 2003).

There is no universal methodology for achieving effective IWM. However, fundamental principles related to cooperation, balance, fairness, integration, communication, and adaptability can help guide the process:

- In most situations, the complexity of information processing and the scope of socioenvironmental change requires cooperation to manage a watershed effectively.
- It requires to balance technical solutions to specific human-generated problems with the wide-scale maintenance of appropriate environmental components that provide similar ecological services.
- Apply regulations guiding the structure and behavior of the socioenvironmental system evenly and fairly throughout the watershed.
- Accept human activities as fundamental elements of the watershed along with the structure and dynamics of the environmental components.

These principles provide only the initial steps in achieving effective watershed management. Cultural values, social behavior, and environmental characteristics will go on develop slowly.
*Consequences of effective IWM is as follows;*
-adequate planning of water resources that is sustainable over many years
-good quality of water that meets legal requirements and protect good ecological factors
- realization of sustainable economic development

## Socio-economic Perspectives

Social, economic, environmental and technical dimensions should be taken into account in an integrated water resources management framework, which will help to initiate and ensure the participation of a large number of stakeholders in the decision-making processes and the development of a cyclic decision making process where feedback will be given at any point (Thomas and Durham, 2003).

For IWM, socio-economic factors include both social issues, such as individual beliefs, related institutions, and stakeholder involvement, and economic issues, such as monetary costs and benefits. IWM goals are determined, in part, by political, economic, institutional, and social demands. Choosing between these demands and balancing them with ecological goals is the challenge of IWM. Developing a successful IWM project requires integrating the complexities of the physical and biological systems with the rules and constraints of the underlying socioeconomic systems. Values and attitudes of stakeholders towards possible restoration outcomes must be considered and incorporated at the beginning of a project, as must the economic costs and benefits, community goals, and institutional constraints related to those outcomes. A successful watershed programme in any area will have its impact on the skill development of the people as well as on their social aspects besides economic impact in terms of increase in the incomes as well as on household expenditure (Prabhakar et al, 2010).

The effects of social and economic factors on IWM have received increasing recognition in the literature (for example, Joshi and others 2004, Mansoor2008, Stinchfield 2009, Dr.Nafo 2010, Prabhakar and others 2010). These studies argue that both socioeconomic and ecological knowledge is necessary for successful IWM.

*Benefits of IWM with respect to socio-economic aspects*

Significant benefits have been obtained from IWM as follows;

- Obtain more rational structure of land use. eg. reduced cultivated farmland, increased forest and grasslands, reduced waste lands.
- Increase the productivity of land and the per capita income of farmers.
- Increase the grain production in the course of the construction of basic farmlands.
- Reduce water and soil losses.
- Achieve significant ecological and social benefits.

Lixian (2002) has studied on pilot watersheds in China and he has published the below mentioned results in his paper ;

1) After proper management, cultivated farmland has been reduced by 5%—10%, forest and grasslands have been increased by 10%—20%, and waste lands have been reduced by 10%—15%. Also the overall ratio of land use has increased by about 20%.

(2) The productivity of land and the per capita income of farmers have increased by 1—2 times.

(3) The grain production has increased by 1—2 times in rain-fed land. In irrigated land, the increase was 3—4 times. Per capita grain supply has reached 300kg—400kg.

(4) Water and soil losses have been reduced significantly. According to analysis of typical watershed, in areas with 50%—79% of land under control, soil and water losses have been reduced by 57%—78% and 46%—76%, respectively. If the degree of control is 80%—100%, the respective figures are 74%— 96% and 70%—92%. The reduction in water and soil losses was beneficial to the downstream of river.

Along with the improvement of ecological environment the habitat of flora and fauna as well as the adjustment of land utilization structure, the renewable resources have been conserved, and the aquatic production, animal husbandry and processing industry are all developing. Hence the livelihood of farmers has been much improved.

*Socio-economic Challenges to Successful Watershed Development and Management*

One of the biggest challenges to IWM is that its costs and benefits are distributed unevenly, yet cooperation is required to make it work. Uneven impacts result from spatial variation and multiple, conflicting uses of natural resources. The conflict between using upper watersheds for protecting them for regeneration to support downstream irrigation is a good example. If the benefits are large and quickly maturing, those who lose in the short term may be willing to wait for gains, and devising mechanisms to diffuse costs may be manageable. But this is more difficult in the majority of cases where benefits are gradual and incremental. Accordingly, watershed projects need to create mechanisms to encourage natural resource utilization consistent with the common good. After the failure of early projects that focused only on technology, beginning about 1990 they more commonly incorporated efforts to promote watershed governance to share net benefits that are simpler task in village-level microwatersheds with established social relationships than in macrowatersheds spanning multiple villages (Kerr, 2007).

## CONCLUSIONS

IWM involves the coordinated use and management of water, land and other biophysical resources within the entire watershed with the objective of ensuring minimal land degradation and erosion and causing minimal impact to water yield and quality and other features of the environment. Therefore, an IWM strategy must be developed for any watershed for the success of the actions towards achievement of sustainability goals (Baloch, 2008).

Increasing populations and higher living standards will requires heavy demands on natural resources in the future. IWM approaches will be necessary to develop sustainable systems and prevent catastrophes. Much greater local, national, and international efforts, cooperation, and expenditures are needed to meet future vital requirements.

In conclusion, IWM has not only one formulation, management strategies should be formed for each watershed according to its own conditions including IWM key components (participation, sustainability etc.). IWM should be flexible enough to accomodate future changes and perspectives.

## RECOMMENDATIONS

IWM is a relatively new concept and its application is very complex, so methodology of IWM application should be private for each watershed. Quick overview of the recent findings and recommendations on IWM activities;

- Sharing experiences and lessons learned
  IWM approaches and methodologies has been achieved in different parts of the world and sharing these results and identifying appropriate mechanisms for disseminating such information are important issues in order to benefit watershed management users/new projects from experiences learned and to avoid the duplication of efforts.
- Using the appropriate participatory processes
  The experience of participatory approaches is important and Participatory processes are recognized as primary at all stages of IWM. Experiences have shown that one-sided bottom-up or top-down approaches do not work. Various approaches and methods should be pragmatically used and adjusted according to specific circumstances.
- Including sustainable and replicable activities.
  The support of all the concerned agencies, organizations, officials and members of the IWM should be solicited to sustain. There should be strong support financially and technically (Paleyan and Wacangan, 2008).
- Reviewing and developing the institutional/organizational and legislative arrangements such as decentralization of authority, interagency collaboration.

- Being adequate IWM policies/strategies
  Coordinators and analysis of the IWM must at all times inform and update through transparency the concerned stakeholders, officers, staff and concerned members in all the IWM activities.

Much greater local, national, and international efforts, cooperation, and expenditures are needed to meet future food and water requirements in sustainable, peaceful, and environmentally responsible ways(Bauver, 2000).

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# NUMERICAL SIMULATING FOR RAIN-WIND INDUCED VIBRATION OF INCLINED CABLES

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**Abstract:** In this paper, the mechanism of rain-wind-induced vibration of inclined cables is further studied based on the theory of multi-degree-of-freedom cable element (Ma, 2003). After both influence of axial and out-of-plan vibrations of cable are neglected, the in-plan vibrations of cable are studied and the influence of water rivulet on aerodynamic forces are considered. A two degree-of-freedom nonlinear model of the coupling system is developed and the governing equations for the vibration amplitude are derived. Then Hurwitz discriminant is used to evaluate the kinematic stability of the system. When the damper or the stiffness of the system is negative, self-excited vibrations of the cable will occur, which is the essence of rain-wind-induced vibration. Because there exits a limited cycle, the free vibration of the nonlinear system has a steady amplitude. By means of the harmonic balance method, the dynamic responses of the system are calculated. Numerical example is given to show that the developed model is reasonable and effective.

**Keywords:** Rain-wind induced vibration, inclined cable

## INTRODUCTION

Rain-wind-induced vibration of an inclined cable is a severe vibration with large amplitude, which might cause fatigue damage in short periods and should be mitigated in engineering. Such dynamic behavior is a solid-liquid-wind interaction problem with complicated mechanism. The forming and the moving of water rivulet on the surface of a cable in wind and rain circumstance changes cable section and aerodynamic forces; the latter, on the other hand, affects the vibration of the cable and the water rivulet. The interactions among the cable, the water rivulet and aerodynamic forces induce self-excited vibration of the system, namely rain-wind-induced vibration. Because of so many infecting factors and the nonlinear characteristics, the mechanism of such vibration is complex and difficult to analyze.

Hikami and Shiaishi (1988) firstly observed rain-wind-induced vibrations on Meikonishi Bridge in Nagoya, Japan, where the amplitudes of inclined cables were observed up to 55cm under wind of velocity 14m/s. During the vibration, a water rivulet was observed to appear on the lower surface of the cable, oscillating in circumferential direction with the same frequency of the cable. Further wind tunnel experimental research showed that the cable oscillations were mostly of single mode in the vertical plane and that the formation position of water rivulets depended on mean wind velocity. Based on further wind tunnel test results and field measurement results, Matsumoto et al. (1992, 1995, 2003) concluded that the formation of upper water rivulet and the axial flowing might be the inducement of rain-wind-induced vibrations. Bosdoginni and Oliver (1996) compared the tunnel test results between fixed water rivulet model and moving water rivulet model and indicated that the position, not the moving, of upper water rivulet was the primary cause of the vibration.

Compared with experimental research, analytical study is relatively limited. Yamagushi (1990) proposed a two-degree-of-freedom galloping model, considering the cable as a horizontal rigid cylinder. After Peng (2001), Xu, Wang (2003) and Wilde, Witkowski (2003) described the movement of rivulet as simple harmonic circumferential oscillating at the frequency of the cable, the plane model was further studied, and the analytical results were compared with those from wind tunnel tests. It turned out that such analytical models could capture main dynamic features of inclined cylinders with either moving rivulet or artificial fixed rivulet. However, because the plane model assumes that the vibration of cable and rivulet is same along cable length, it might not be applicable to an integral cable. A multi-degree-of-freedom cable model was developed by Ma in 2003, where the inherent modes were used to simulate the dynamic curve of the cable, and the oscillation of rivulet was explored. However, as a further study, this paper presents a two degree-of-freedom nonlinear model of the coupling system after both influence of axial and out-of-plan vibrations of the cable being neglected. Then Hurwitz discriminant is applied to evaluate the kinematic stability of the model and the harmonic balance method is employed to calculate the amplitude of the cable.

## Theoretical model

The mechanical model is shown in Fig.1, where x is chord direction of the cable, and θ is the inclination angle. S is the average tension along the chord. $z_1$ is the local orientation in the moving direction of the cable. $\beta(x,t)=\beta_0(x)+\gamma(x,t)$ is the instant position of the rivulet, $\beta_0(x)$ and $\gamma(x,t)$ are the initial position and oscillating angle of the rivulet, respectively. $U(x)$ and $U_{RE}(x,t)$ are wind velocity and relative velocity.

As the cable oscillations are mostly of a single mode in the vertical plane, the dynamic curve of the cable can be simulated through its inherent vibration in-plane mode functions. After both influences of axial and out-of-plan vibrations are neglected, the multi-degree-freedom model of Ma (2003) may be simplified as

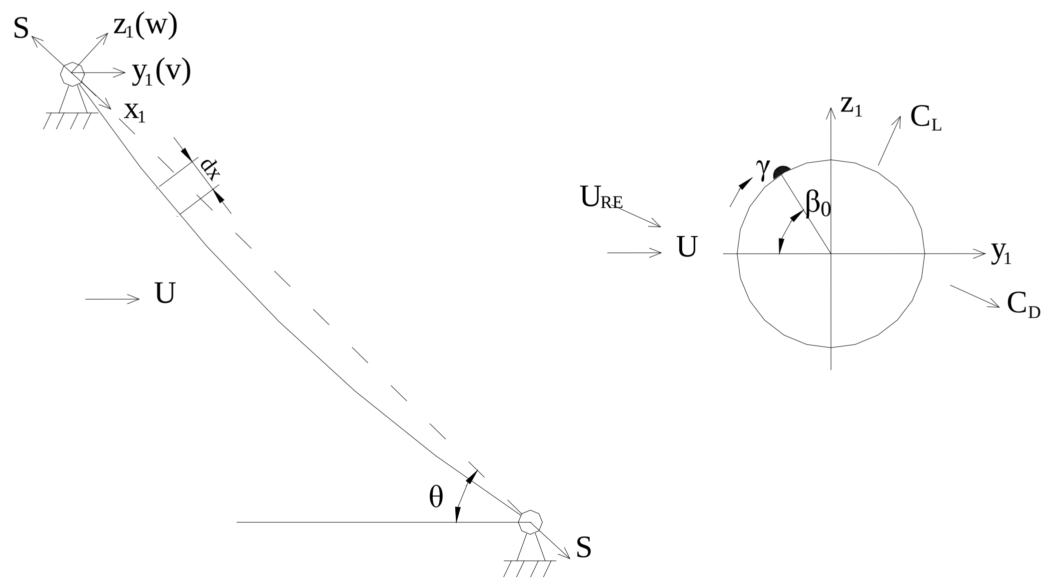


Figure. 1 Model of the system of cable and rivulet

$$m_{11}\ddot{q}_w + c_{11}\dot{q}_w + k_{11}q_w + k_{12}q_w^2 = f_w \tag{1}$$

$$m_{21}\ddot{q}_w + m_{22}\ddot{q}_\gamma = g_1\ddot{q}_w q_\gamma \tag{2}$$

where $m_{11} = M\int_0^l \phi_w^2 dx$, $m_{21} = mD/2\int_0^l \phi_w \phi_\gamma \cos\beta_0 dx$, $m_{22} = m\left(\frac{D}{2}\right)^2 \int_0^l \phi_\gamma^2 dx$,

$g_1 = mD/2\int_0^l \phi_\gamma^2 \phi_w \sin\beta_0 dx$, $f_w = \int_0^l F_{z1}\phi_w dx$, $k_{11} = -S\int_0^l \phi_w''\phi_w dx + \frac{EA}{l}\int_0^l z_1''\phi_w dx \int_0^l z_1'\phi_w' dx$,

$\phi_\gamma(x) = \cos\beta_0(x)\phi_w(x)$, $\phi_\gamma(x)$ is the vibration mode of the rivulet, $\phi_w$ is the in-plane mode function of the cable, $c_{11}$, $l$ and $D$ are the damper coefficient, chord length and the diameter of the cable, k is the rotation stiffness of the rivulet, $z_1(x)$ is the initial curve function of the cable, $w(x,t)$ is the vertical dynamic displacement, *EA* is the section stiffness, *M* and *m* are the mass per unit length of the cable and the rivulet. $F_{z1}$ is the wind pressure component in $z_1$direction:

$$F_{z1} = \rho D U_{RE}^2[-C_D \cdot \sin\alpha^* + C_L \cdot \cos\alpha^*]/2 \quad (3)$$

where $C_L(\alpha), C_D(\alpha)$ are lift and drag coefficient, respectively and may be expressed as

$$C_D(\alpha) = C_{D0}(x) + C_{D1}(x)\cdot(\gamma - \alpha^*) + C_{D2}(x)\cdot(\gamma-\alpha^*)^2 + C_{D3}(x)\cdot(\gamma-\alpha^*)^3 \quad (4)$$

$$C_L(\alpha) = C_{L0}(x) + C_{L1}(x)\cdot(\gamma - \alpha^*) + C_{L2}(x)\cdot(\gamma-\alpha^*)^2 + C_{L3}(x)\cdot(\gamma-\alpha^*)^3 \quad (5)$$

$$\alpha^* = \arctan(\dot{w}/U) \quad (6)$$

where $\gamma(x,t) = q_\gamma(t)\phi_\gamma(x)$, $w(x,t) = q_w(t)\phi_w(x)$.

Combining equation (1), (3), (4), (5), we get

$$\ddot{q}_w + 2\xi_w\omega_w\dot{q}_w + \omega_w^2 q_w + k_{12}/m_{11}q_w^2 = \rho D U^2/m_{11}\cdot g_w \quad (7)$$

where

$g_w(q_\gamma, \dot{q}_w) = a_0 + a_1\dot{q}_w + a_2\dot{q}_w^2 + a_3\dot{q}_w^3 + a_4 q_\gamma + a_5 q_\gamma^2 + a_6 q_\gamma^3 + a_7\dot{q}_w q_\gamma + a_8\dot{q}_w^2 q_\gamma + a_9\dot{q}_w q_\gamma^2$

$a_0 = \int_0^l C_{L0}\phi_w dx$, $a_1 = \int_0^l(-C_{D0} - C_{L1})\phi_w dx/U$, $a_2 = \int_0^l(C_{D1} + C_{L0}/2 + C_{L2})\phi_w dx/U^2$,

$a_3 = \int_0^l(C_{D0}/2 - C_{D2} - C_{L1}/2 - C_{L3})\phi_w dx/U^3$, $a_4 = \int_0^l C_{L1}\phi_w dx$, $a_5 = \int_0^l C_{L2}\phi_w dx$, $a_6 = \int_0^l C_{L3}\phi_w dx$,

$a_7 = \int_0^l(-C_{D1} - 2C_{L2})\phi_w dx/U$, $a_8 = \int_0^l(2C_{D2} + C_{L1}/2 + 3C_{L3})\phi_w dx/U^2$, $a_9 = \int_0^l(-C_{D2} - 3C_{L3})\phi_w dx/U$,

$\omega_w, \xi_w$ are the circular frequency and damper ratio of the cable.

Similarly, equation (2) may be rewritten as

$$m_{21}/m_{22}\ddot{q}_w + \ddot{q}_\gamma = g_1/m_{22}\ddot{q}_w q_\gamma \quad (8)$$

## Judgment for the stability of the governing equation

The linearized equation of the system is

$$\mathbf{M}\ddot{\mathbf{q}} + \mathbf{C}\dot{\mathbf{q}} + \mathbf{K}\mathbf{q} = 0 \quad (9)$$

where $\mathbf{M}=\begin{bmatrix}1 & \\ m^* & 1\end{bmatrix}$, $\mathbf{C}=\begin{bmatrix}c_{11} & 0\\ 0 & 0\end{bmatrix}$, $\mathbf{K}=\begin{bmatrix}\omega_w^2 & k_\gamma\\ 0 & 0\end{bmatrix}$, $\mathbf{q}=\begin{Bmatrix}q_w\\ q_\gamma\end{Bmatrix}$, $k_\gamma=-\rho DU^2/m_{11}a_4$,

$c_{11}=2\xi_w\omega_w-\rho DU^2/m_{11}a_1$, $m^*=m_{21}/m_{12}$.

The characteristic polynomial of equation (9) is

$$G(\lambda)=\det(\mathbf{M}^*\cdot\lambda^2+\mathbf{C}^*\cdot\lambda+\mathbf{K}^*)=\lambda^2\left(\lambda^2+e_1\lambda+e_2\right) \tag{10}$$

where $e_1=c_{11}$, $e_2=\omega_w^2-m_\gamma^* k_\gamma$

Equation (9) remains stable, when all the eigenvalues of equation (10) has negative real part. According to Hurwitz criterion, the condition requires that the inequalities

$$g_i>0 \qquad i=1,2 \tag{11}$$

be satisfied, where $g_1=e_1$, $g_2=e_1e_2$. Since $e_2$ is positive for usual wind velocity, the stability of equation (11) only depends on the sign of $e_1$, or $c_{11}$. When damper of the system $c_{11}$is positive, the system remains stable; otherwise rain-wind-induced vibration occurs. The result is similar to that of the plane models and wind-tunnel test results.

## Calculations for cable amplitude

As the nonlinear terms of response appear in the right side of equation (7), the amplitude of cables will not increase unlimitedly. There exists steady vibration with constant amplitude for the system when rain-wind-induced vibration occurs. The harmonic balance method is employed in the paper.

The dynamic response of steady vibration of the cable can be expressed as

$$q_w=A_w\cos\omega t \tag{12a}$$

$$\dot{q}_w=-\omega A_w\sin\omega t \tag{12b}$$

$$\ddot{q}_w=-\omega^2A_w\cos\omega t \tag{12b}$$

Considering phase difference，the dynamic response of rivulet can be expressed as

$$q_\gamma=A_{\gamma1}\cos\omega t+A_{\gamma2}\sin\omega t \tag{13a}$$

$$\dot{q}_\gamma=-\omega A_{\gamma1}\sin\omega t+\omega A_{\gamma2}\cos\omega t \tag{13b}$$

$$q_\gamma=-\omega^2\left(A_{\gamma1}\cos\omega t+A_{\gamma2}\sin\omega t\right) \tag{13c}$$

Substituting (12) and (13) into (7), and considering that coefficients of $\cos\omega t,\sin\omega t$ equal to those on the other side of the equation, one gets

$$A_w(-\omega^2+\omega_w^2)=b_7A_{\gamma1}+\frac{1}{4}b_5\omega^2A_w^2A_{\gamma1}-\frac{1}{2}b_4\omega A_wA_{\gamma1}A_{\gamma2}+\frac{3}{4}(b_2A_w^3+b_9A_{\gamma1}^3+b_9A_{\gamma1}A_{\gamma2}^2) \tag{14a}$$

$$-\omega c_{11}A_w=b_7A_{\gamma2}-\frac{3}{4}(b_3\omega^3A_w^3-b_5\omega^2A_w^2A_{\gamma2})-\frac{1}{4}b_4\omega A_w(A_{\gamma1}^2+3A_{\gamma2}^2)+\frac{3}{4}b_9A_{\gamma2}(A_{\gamma1}^2+A_{\gamma2}^2) \tag{14b}$$

$$-\omega A_{\gamma1}+c_\gamma^*\sqrt{A_{\gamma1}^2+A_{\gamma2}^2}A_{\gamma2}=m^*\omega A_w(1+\frac{3}{8}d_1A_{\gamma1}^2+\frac{1}{8}d_1A_{\gamma2}^2) \tag{14c}$$

$$-\omega A_{\gamma2}+c_\gamma^*\sqrt{A_{\gamma1}^2+A_{\gamma2}^2}A_{\gamma1}=\frac{1}{4}d_1m^*\omega A_wA_{\gamma1}A_{\gamma2} \tag{14d}$$

$$b_i = \rho D U^2 / m_{11} \cdot a_i \quad i = 1, \cdots 9 \tag{14e}$$

$$d_1 = \int_0^l \sin \beta_0 \phi_\gamma^3 dx / \int_0^l \phi_\gamma^2 dx \tag{14f}$$

Thus the nonlinear governing equation (7) is changed into an algebra equation group (14), containing unknowns $\omega, A_w, A_{\gamma 1}, A_{\gamma 2}$.

## Example

The longest cable of Yangzi River Bridge is 334m long. The parameters of the cable are as following (Peng 2001): diameter $D$=0.145m, Section stiffness $EA$=1,900,000 kN, mass density M =85kg/m, damper ratio $\xi_w$ =0.1%, inclination angle $\theta=29^o$. The mass density of the rivulet is 0.17kg/m. The stability judgment parameters are shown in Fig. 2 indicating that the rain-wind vibration occurs with the wind speed between 8.4m/s and16.4m/s. The stable amplitudes with different wind speeds are shown in Fig. 3 with comparison of Peng's results (2001).

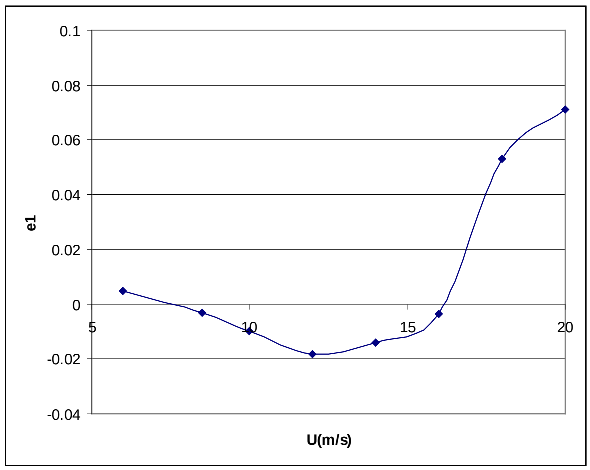


**Figure 2.** The stability parameters of the system with different wind speed

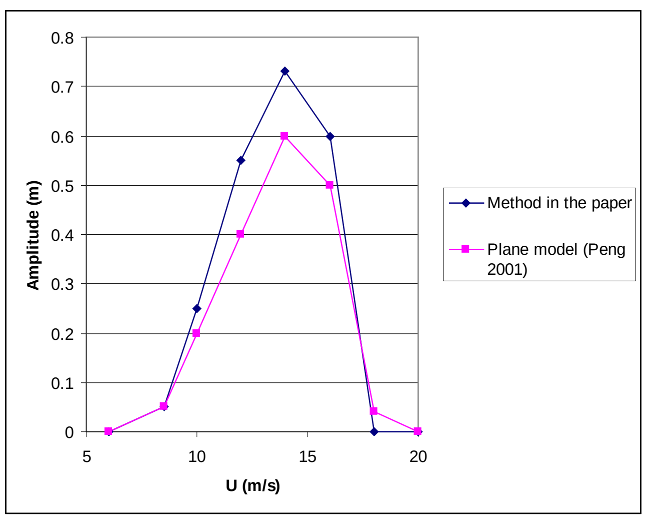


**Figure 3.** Amplitudes of the cable with different wind speed

## CONCLUSION

Considering the in-plane vibration of the cable and the influence of the rivulet position to the aerodynamic forces, a two-degree-freedom model is derived to analyse the rain-wind-vibration of inclined cables and the harmonic balance method is employed to calculate the vibration amplitudes. From analysis above, it may be concluded that the mechanical essence of the complex dynamics phenomenon is a self-excited nonlinear vibration with constant amplitude induced by negative damper.

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# REMOVAL OF FINE PARTICLES FROM WASTEWATER USING INDUCED AIR FLOTATION

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**Abstract:** The suspended solids must be removed from effluent prior to re-using or discharging into environment. In order to remove the fine particles, large basins are needed to provide sufficient retention time due to the extreme low settling velocities, therefore flocculants or coagulants have to be added to increase the settling velocity and efficiency of settling basins. For removing suspended particles from wastewaters, flotation and floc-flotation methods are getting attention recently due to their advantages over the other methods. In this study, IAF process (Induced Air Flotation -Jameson Flotation) was applied to synthetic wastewater containing fine quartz particles. Preliminary results of flotation experiments which were carried out by Jameson flotation cell were given. Effect of particle size and solid/liquid ratio on the turbidity removal efficiency was researched. The synthetic wastewater samples containing suspension of very fine quartz particles was pre-treated with/without anionic flocculant addition and then introduced to the Jameson flotation cell with cationic type collector (amine). Reasonable turbidity removal efficiencies were obtained for the particles larger than 20 µm, however the results were not good as for the -20 µm particles. The experimental works have shown that over 90 % turbidity removal efficiency of -20 µm particles was possible at the lowest solid/liquid ratio (0.06 %) tested when floc-flotation studies was applied by Jameson cell.

**Keywords*:*** Wastewater treatment, flotation, flocculation, induced air flotation, Jameson cell.

## INTRODUCTION

A large amount of wastewater from industrial and municipal usage has been generated due to the faster development of urbanization and technology, and hence, the increase in production and consumption. These wastewaters have been given to the nearest rivers, lakes, seas, etc. From this point of view, the necessity of wastewater control before disposing them to the environment is a very important topic (Russel, 2006). The wastewater containing fine particles is generally pretreated through sedimentation, filtration and flotation methods prior to discharge or recycled to reuse the treated wastewater instead of fresh water (Şener, 2007). In order to remove fine particles flocculation and coagulation methods are commonly applied to provide sufficient retention time to settle the slow settling fines (Gregory, 2005; Bratby, 2006).

Selection of wastewater treatment process is generally based on several factors such as the wastewater characteristics, the effluent standards to be met and the cost of treatment. The settling tank is designed for an overflow rate of 1-2 m/h. This may be considerably increased by the use of polymers as flocculants. An alternative to traditional settling is the use of flotation. Flotation tanks are designated for much higher overflow rates (5-15 m/h) and they can give a better separation results since smaller particles may be removed (Odegaard, 2001).

The flotation experience in the mineral processing area has been extended to wastewater treatment for many decades, broadening its potential for wastewater treatment (Rubio at al., 2002;

Rosa and Rubio, 2005). Finely dispersed air bubbles are brought into contact with the chemically conditioned wastewater stream where particle bubble attachment occurs. The particle ladened bubbles float to the surface where they are removed from the wastewater stream being treated (Jameson, 1999; Orr, 2000; Kotze, et al., 2001; Yan and Jameson, 2004).

In mineral flotation the particles are quite large, typically having diameters of 50 µm or more (Matis and Zouboulis, 1995). Therefore, bubbles have to be large usually of the order of 1 mm, while the solid content in the pulp is normally high, of the order of 25 % by weight and a high selectivity between solids is generally wanted (Matis and Zouboulis, 1995). In effluent treatment by contrast, the particles are typically small (less than 20 µm in diameter), close to neutral buoyancy, and present in very dilute concentrations, often as low as 50 mg/L or $50x10^{-4}$ % w/v (Matis and Zouboulis, 1995). Since the particles in the feed of wastewater flotation are usually very small and often within the colloidal range, depending on the density, since larger particles are more easily removed by a simple gravity settler. To increase the mean particle size and thus increase the rate of collection by the air bubbles, the particles are usually treated with a flocculant or coagulant (Jameson, 1999).

Many flotation methods were developed in wastewater treatment and developments have been still continuing. The dissolved air flotation (DAF) is more common in the treatment of wastewater (Colic at al., 2007). Recently, the other flotation method offering many advantages over DAF is induced air flotation (IAF). In IAF, the air can be entered to the system without needing a compressor. In DAF, the size of the bubbles generated when the pressure of the air-saturated feed is reduced is very small (100 µm<). While such bubbles very effective in the collecting flocs and small particles, they also have correspondingly small terminal velocities, leading to relatively large equipment sizes. The use of larger bubbles are found in IAF, can lead to the development of flotation systems which are much more compact, provided proper attention is paid to the surface chemistry of the particles or flocs to be floated (Jameson, 1999).

The air bubbles occurred in classical IAF is much bigger than those needed for wastewater flotation and do not suitable for the process. Jameson developed an improved version of IAF (Jameson, 1988). The Jameson IAF cell was developed initially for the flotation of fine coal and metallic ores (Evans, et al., 1995). It has been adapted for the treatment of wastewater in 1994. Some of the most important advantages of Jameson IAF over DAF are: the flocs generated are floated in a short time period, the sludge floated contains higher solid ratios, the device has more compact design (much smaller than DAF) and it can be operated at higher degrees (up to 70 $^{0}$C) (Jameson, 1999; Yan and Jameson 2004).

The aim of this study was to research the potential usage of Jameson flotation cell in removal of suspended quartz particles. Previously, the studies about quartz flotation in Jameson Cell has been published by us (Taşdemir et al., 2007) using the cationic collector of aeromine and by Çınar et al. (2007) using dodecylamine system. These studies were based on recovery of quartz removal containing high particle concentrations and higher particle sizes. In this research, we tried to float the quartz particles from synthetically prepared wastewater suspensions which have very low particle concentrations. Synthetic suspended wastewater samples were prepared at different size fractions and different solid/liquid ratios. The samples which were pre-treated with or without using anionic flocculant were subjected to flotation tests in Jameson cell by using cationic type collector (amine). Preliminary results of turbidity removal experiments are given here.

## MATERIALS AND METHOD

Synthetic wastewater samples containing fine quartz particles for flotation were prepared. The pure quartz sample used in the experiments was obtained from the Milas-Çine region of Turkey. The sample was sized to three fractions as -53+38 µm, -38+20 µm and -20 µm.

To search the relation between solid/liquid ratio and turbidity of quartz particles used in the experiments, turbidity measurements were carried out for different size fractions. Turbidity values of suspended quartz particles at different size fractions are given in Fig.1 as a function of solid ratio. As it is seen in this figure, turbidity increases with increasing solid ratio in the wastewater sample as expected. There are exponential relation between the solid ratio and turbidity. Different turbidity values were obtained at same solid ratios for different size fractions. As the particle size decreases, higher turbidity values are obtained for the same solid ratio in the samples. Therefore, higher turbidity values are obtained for the -20 µm with the same quantity of powder compared to larger sizes.

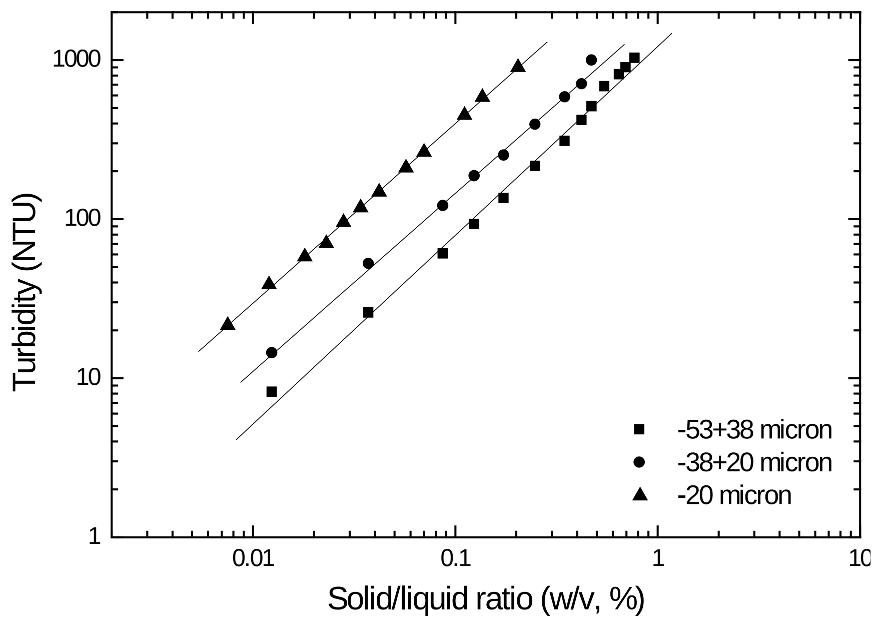


**Figure 1**. Turbidity values of different sized quartz particles in synthetically prepared wastewater samples as a function of solid ratio.

An experimental setup used in this study is shown in Figure 2. It consists of a separation tank (145 mm), downcomer (25 mm), a conical type nozzle (3 mm), pressure gauge on the feed line, air flow rotometer on the air line, conditioning tank with stirrer. The separation tank and the downcomer were made of transparent plexiglas. Wastewater and reagents were conditioned in the tank before flotation. After conditioning, wastewater feed is delivered to the nozzle under the high pressure by means of a peristaltic pump. The pulp comes out of the nozzle with a great speed and takes the air with it to the pressure difference. The air broke up into fine bubbles and created a very favorable environment for collision of particles and bubbles. The bubbles which are loaded with particles disengage from the wastewater and rise into the froth layer.

In the flotation tests, the feed flow rate was controlled with control panel of feed pump; thus, desired flow rates of feed slurry can be adjusted. Similarly, a peristaltic pump with a control panel for the end of cell was used for the recirculation of the cleaned effluent to the feed tank. The system was operated at closed circuit through the experiments at a steady state. The floated sludge did not circulated to the feed tank again and obtained as separately, but the residual slurry in the separation tank was sent to the feed tank. After 10 minutes of flotation time, the residual turbidity was measured as NTU (Nepheleometric Turbidity Unit) by using HF Scientific turbidimeter which has 0-1000 NTU measurement ranges. The turbidity removal efficiencies were calculated as a result.

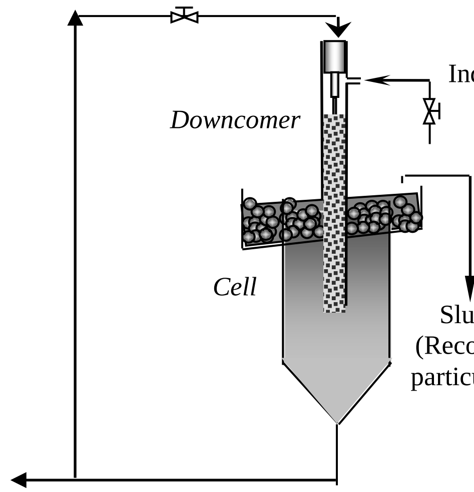


**Figure 2.** Experimental setup of Jameson cell

## EXPERIMENTAL

The synthetic wastewater prepared by using different sized quartz samples at different solid/liquid ratio was treated by a laboratory scale Jameson cell. Experimental conditions of flotation tests are given in Table 1. Feed flowrate, feed pressure, jet length, jet velocity conditioning time and pH were held constant in all experiments. In each case, the conditioning tank was filled with 20 liters of water and sized quartz to achieve a certain percent solid. The collector (Aeromine produced by Cytec in the Netherlands and the frother (Aerofroth 65 produced by Cytec in the Netherlands) dosages were held constant as 500 gr/t and 20 ppm respectively during the experiments. The collector was added and conditioned for five minutes. The frother was added and conditioned for a further two minutes.

**Table 1**. Experimental conditions of flotation tests

| | |
|---|---|
| Immersion depth of downcomer (cm) | 70 |
| Nozzle diameter (mm) | 3 |
| Jet length (cm) | 3 |
| Feed pressure (KPa) | 110 |
| Feed flowrate (L/min) | 7 |
| Jet velocity (m/sec) | 16.5 |
| Conditining time (min) | 5 |
| pH | 8 |
| Frother (AF65) dosage (ppm) | 20 |
| Collector (Aeromine) dosage (g/t) | 500 |
| Flocculant (Anioic) dosage (mg/L) | 0.06 ; 0.1; 0.5 |
| Particle size (µm) | -53+38; -38+20;-20 |
| Solid/liquid ratio (%) | 0.06; 0.1; 0.5 |

## RESULTS AND DISCUSSION

The first preliminary flotation tests were carried out without flocculant addition. The preconditioned feed slurry having different size and solid ratio was introduced to the Jameson cell. The comparative results of residual turbidity measurements obtained are given in Fig.2. It is seen that solid ratio and the particle size are very important parameters during flotation in Jameson cell, with increasing solid ratio leading to higher turbidity removal recoveries in all size fractions (Fig. 3). The low turbidity removal results at low solid ratios are mainly due to the low probability of bubble-particle collision. The turbidity removal efficiencies for particles larger than 20 µm are higher compared to -20 µm particles. This is due to the fact that as the particles are getting smaller the collision probability between air bubbles and the particle's surface decreases. However, turbidity removal efficiency decreases with increasing of particle size (>38 µm) for lower particle concentrations. The main reason for poor flotation recovery of coarse particles is the high probability of detachment of particles from the bubble surfaces. In general, collision probability increases with increasing particle size and decreasing bubble size. In general, the size of bubbles in Jameson Cell varies between 300-600 micron (Evans, et al., 1995). Fine particles have low probability of collision with bubbles and are thus difficult to catch by bubbles. This is the main reason for the low flotation rate of fine particles.

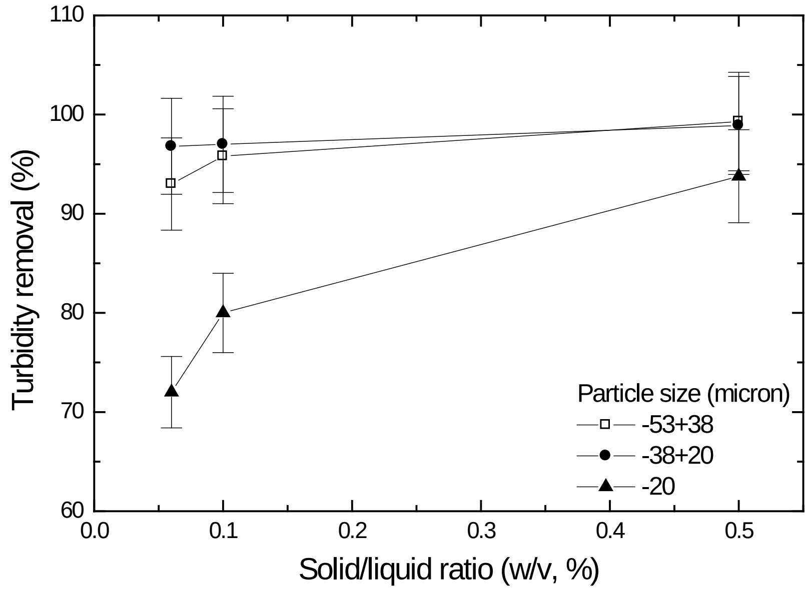


**Figure 3.** Effect of solid ratio and particle size on turbidity removal without flocculant addition.

To improve the turbidity removal efficiency of -20 µm size fraction, two stage flotation experiments were carried out at different solid ratios. In two stage flotation experiments, the residual wastewater was floated after adding the collector and conditioning 5 minutes, then this conditioned slurry was subjected to Jameson cell for additional flotation. The results of residual turbidity measurements obtained from the single and two stage flotation tests are shown in Fig. 4. Applying two stage flotation increased the turbidity removal efficiency for all solid ratios of -20 µm. These indicate that better turbidity removal efficiency of suspended particles can be achieved when the two stage flotation was applied. The lowest turbidity removal efficiency was achieved about 85 % for the 0.06 % solid ratio.

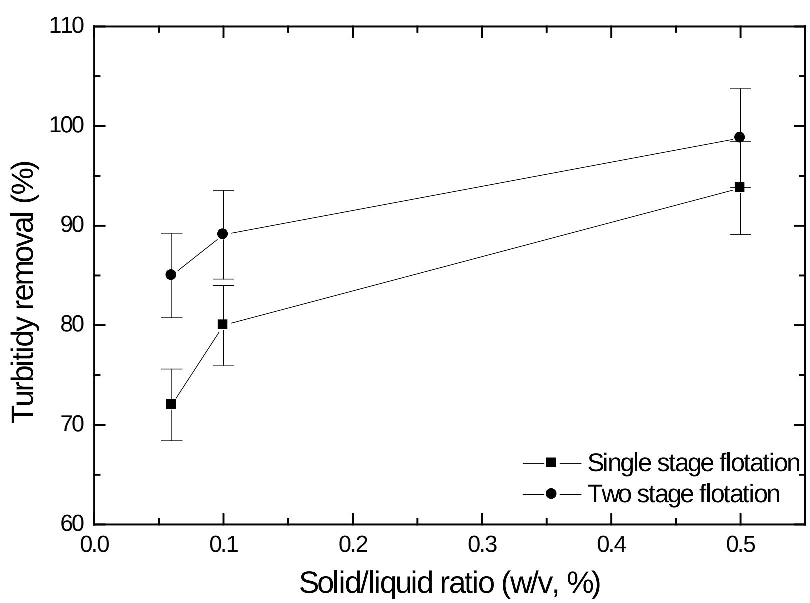

**Figure 4.** The turbidity removal results of -20 µm size in the single and two stage flotation at different solid ratios without flocculant addition.

Floc-flotation experiments were also made for the -20 µm size fraction to search the effect of flocculation process on the turbidity removal efficiency. In a previous study (Taşdemir and Erdem, 2010), the effects of some flocculation parameters such as flocculant type, molecular weight of flocculant, flocculant dosage, pH of suspension and mixing speed on flocculation process were examined in details for synthetic wastewater samples containing pure quartz particles. According to that study, the best result was obtained when anionic flocculant having high molecular weight was used at pH 8.

The samples containing different solid ratios were preconditioned with anionic type flocculant (SPP 508) which was supplied from Süperkim Chemistry Co. According to jar tests which made for -20 µm size fraction, the optimum dosages of the flocculant was determined as 0.06 mg/L, 0.1 mg/L and 0.5 mg/L for 0.06 %, 0.1 % and 0.5 % solid ratios respectively.

Flotation results of Jameson cell obtained are given in Fig. 5. The turbidity removal efficiency was very high for the particles preconditioned by flocculants than non-flocculated particles. Over 90 % turbidity removal efficiency was achieved for the lowest solid/liquid ratio (0.06 %). The results better for the higher solid/liquid ratio samples. After flocculating the fine particles, the collision probability between the flocs and bubbles generated would increase compared to non-flocculated particles.

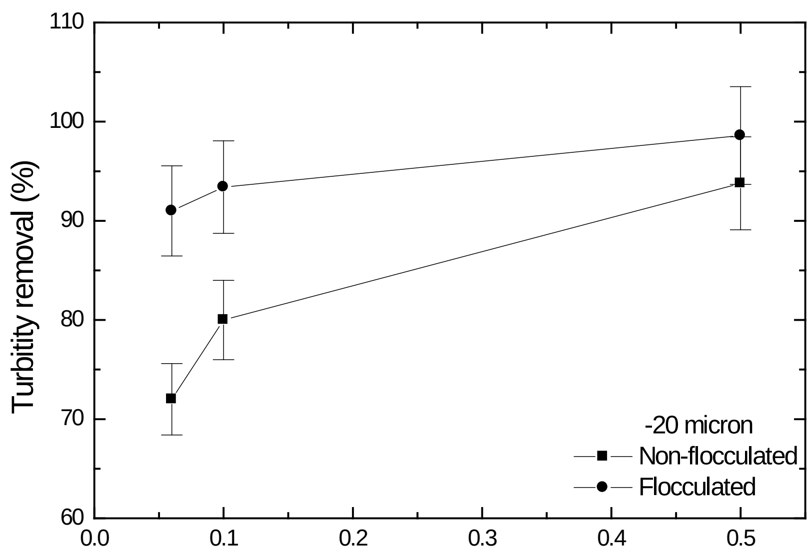


**Figure 5.** Effect of flocculant on turbidity removal of -20 µm size fraction at different solid ratios.

Based on the zeta potential measurements, the surface charge of quartz is found negative after pH 3 in literature (Viera and Peres, 2007). Achieving high turbidity removal efficiency with anionic type flocculant cannot be explained by physical adsorption of flocculant molecules on the quartz surface. It can be troughed that cationic flocculant might give better results with quartz removal since the surface charge of quartz at pH 8 is negative. But according to results anionic type flocculant gave better results than the cationic flocculant for quartz flocculation (Taşdemir and Erdem, 2010). This is due to different flocculation mechanisms of flocculants and here the bridging mechanism is effective for the quartz flocculation with anionic flocculant. Bridging is considered to be consequence of the adsorption of the segments of flocculant macromolecules onto the surfaces of more than one particle (Tripathy and Ranjan 2006; Şener, 2007).

## CONCLUSIONS

Induced air flotation based on the Jameson cell technology has been applied successfully to the removal of synthetically prepared suspended particles in wastewaters. With proper condition of the feed water, the particles which are greater than 20 µm in the wastewater samples can be removed effectively by a single flotation stage without using flocculant. The increase in solid ratio increased the turbidity removal efficiency of all size fractions. Compared to larger particles, the results were not good for the particles smaller than 20 µm. Two stage flotations ensured to improve the results of this size fraction. When the -20 µm sizes of quartz samples was pre-conditioned by the anionic flocculant it was possible to obtain over 90 % turbidity removal efficiency in single stage flotation for the lowest solid ratio (0.06 %) and higher efficiencies for higher solid/liquid ratios tested. The main advantages of Jameson cell are rapid collection of particles in the downcomer and relatively small footprint, high throught, rapid start-up and low chemical usage, the ability to operate at elevated temperatures. Therefore it offers technical advantages over existing technologies for a range of new applications.

## ACKNOWLEDGEMENTS

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# TRUCK CHASSIS STRUCTURAL THICKNESS OPTIMIZATION WITH THE HELP OF FINITE ELEMENT TECHNIQUE

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**Abstract:** Heavy duty vehicles like trucks, has wide range of structural and conceptual design. In Turkey ground transportations and heavy duty works like mine and rock transportation are made with Long Vehicles and especially with middle tonnage trucks (10 – 40 tones). Many truck chassis manufacturers use thick profiles for the chassis for reliability of the frame. Using more than enough material causes expensive product manufacturing conditions. To reduce the expenses of the chassis of the trucks, the frame's structure design should be changed or the thickness should be decreased. In this study, for manufacturing reliable and inexpensive middle tonnage truck chassis, used chassis structures by some manufacturers are optimized by the thicknesses of the profiles. This study showed that the thinner chassis profiles can be reliably used in the truck chassis sections with the help of structural finite element analysis.

**Keywords:** Truck Chassis, Finite Element Technique, Thickness Optimization

## INTRODUCTION

For more strength and reliable frame of the trucks, all manufacturers are trying to produce strong and cumbersome chassis. Every strength increase of the chassis by adding beams and structural elements makes the whole frame heavier and more expensive. The easiest technique for reducing both weight and cost of the chassis is using less chassis member or decreasing the thickness of the profiles sections. Initially, the most important part of the frame design is, the chassis reliability and safety. When decreasing the thickness of the sections the optimal design criteria should have been considered. For making a cheap truck frame might cause a destructive accident results and fatality. To make a reliable and inexpensive design thickness and cost optimization should be examined with details.

For understanding the robustness of the chassis or vehicle body by the strength tests of the members and whole frame, different studies were widely carried out as it is mentioned below.

Every vehicle has a body, which has to carry both the loads and its own weight. Vehicle body consists of two parts; chassis and bodywork or superstructure. The conventional chassis frame, which is made of pressed steel members, can be considered structurally as grillages. The chassis frame includes cross-members located at critical stress points along the side members. To provide a rigid, box-like structure, the cross-members secure the two main rails in a parallel position. The cross-members are usually attached to the side members by connection plates. The joint is riveted or bolted in trucks and is welded in trailers [1, 2].

When rivets are used, the holes in the chassis frame are drilled larger than the diameter of the rivet [2]. The rivets are then heated to an incandescent red and driven home by hydraulic or air pressure. The hot rivets conform to the shape of the hole and tighten upon cooling. An advantage of this connection is that it increases the chassis flexibility. Therefore, high stresses are prevented in critical area. The side- and cross-members are usually open-sectioned, because they are cheap and easily attached with rivets. An experimental and numerical analysis of riveted joints was studied by Fung and Smart [3]. A three-dimensional finite element model of a riveted lap joint was formulated with shell elements and elastic supports to allow for simulation of various levels of load transfer [4]. Xiong used analytical and numerical methods, for the stress analysis of riveted lap joints in aircraft structures [5]. In the numerical method, finite element analyses were conducted using some commercial packages. Nut and bolt construction are also used in chassis frame as this allows easy removal of components for repair or replacement purposes. As far as joint modeling techniques are concerned, there are many studies to determine the joint stillness in bolted connections through detailed finite element modeling or experiments [6, 7].

Different static or dynamic testing methods and variety of failure criteria are major diverging factors especially in Finite Element Method. Although the scope of these regulations does overlap for some groups of vehicles, none of the regulations specifically address paratransit style vehicles. This lack of regulation is troubling because the overall stiffness and resistance of the vehicle depend very much on the structural design solutions, applied materials, the connection to the vehicle chassis, and especially the connections between the major body components. All of these factors are dependent solely on the body builder, and as such can vary widely with the company's resources and experience [8].

The usual economic forces of reducing numbers of prototypes, minimization of testing/design iterations, optimizing gages and weight, and shortened design cycle time are driving people toward this objective. The vision is to 'drive' a computerized vehicle over a digital version of the proving grounds, observe the vehicle load responses, and 'watch' the stress histories on any or all of the elements that model the body and components of the vehicle. After geometry or thickness optimization the procedure is repeated until the achievement of the design life standard at minimum weight [9].

The body (i.e. the tray) of a large rear-dump mining truck generally accounts for 20}25% of the total empty vehicle mass and is the heaviest single item of the truck. In a typical 172-t capacity truck, the body weighs about 29 t. Therefore, one way to reduce the mass of the truck, and hence increase its load-carrying capacity, is to reduce the mass of the body [10]. The reason is of course that the designer makes an effort to reduce the mass of the structure, while limiting the deformation. It is inevitable that stress levels increase and that the deformations for the as-loaded condition increase [11].

In automotive and aerospace industries, engineers are challenged to design load-carrying components that are strong enough to sustain heavy impact, cyclic or random loads for structural integrity of the mechanical system. Such components must also contain a minimal amount of material to reduce material consumption in production and increase the efficiency of the mechanical system, such as fuel consumption. The geometry of the load-carrying components is usually complicated due to strength and efficiency requirements. Such requirements often increase manufacturing cost of the component [12].

Structural optimization research has been conducted for many decades, addressing mainly functionality aspect of the structural design [12-15]. Reliability issues have been addressed for design in recent years [16-18]. However, manufacturability, which plays a significant role in determining the cost of the engineering product, has not been widely incorporated for structural optimization [12].

In this study for manufacturing robust and economic middle tonnage truck chassis, used chassis structures by companies are optimized by the thicknesses of the profiles. In daily usage, Turkish truck chassis companies are manufacturing frames, thickness of 6mm. For determining the strength of the frame, structural analyses were performed for these frames of thicknesses of 6mm, 5mm and also 4mm. The truck chassis was modeled in Pro_Engineer and the finite element analyses were solved in Pro_Mechanica.

## MATERIALS

In the chassis manufacturing technology, especially steel and its alloys are used for the material of the frame geometry. For the frame models, wide variety of materials, composite materials and different kind of alloys can be used. In the present study, manufacturer doesn't want to change its material type because of the supplier and not to changing their manufacturing methods and materials etc. Truck Chassis Company uses St 52.3 steel for the whole chassis geometry in Istanbul, Turkey. The material properties of the St 52.3 steel is given in table 1.

**Table 1:** Material properties of the Truck Chassis (St 52.3).

| | |
|---|---|
| Young Modulus | 199GPa |
| Poisson Ratio | 0.27 |
| Density | 7827.08kg/m$^3$ |
| Symmetry | Linear isotropic |

In the finite element analysis of the truck chassis, linear isotropic material model of St 52.3 was used.

## MODELING AND OPTIMIZATION ANALYSIS

The chassis manufacturer in Istanbul, Turkey wants to reduce the expenses of the company and the truck chassis structure. First step to reduce the expenses is decrease the cross members of the truck chassis. In the chassis just main members are used as needed. It is not a choice to use fewer members in frame.

The second way to decrease the cost of the frame is using thinner sections for the profiles. There should be a limit for the thickness. If the limit is exceeded, the truck chassis is no longer robust or reliable. Initial CAD part of the truck chassis was modeled in Pro_Engineer. Constrained and loaded CAD model can be seen in figure 1.

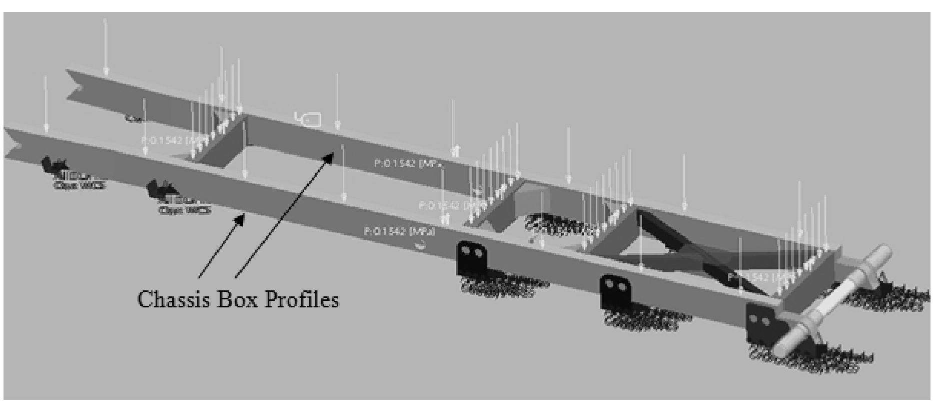


**Figure 1.** Truck chassis and loading condition.

For the distributed load values, manufacturer's data tables were used. 156.96kN (16t) distributed load was applied to the whole chassis geometry (Figure 2). In addition the pressure for the whole top surfaces (0.1542MPa) can be determined in figure 1. Chassis was held from the bolt holes of the brackets in All DOF.

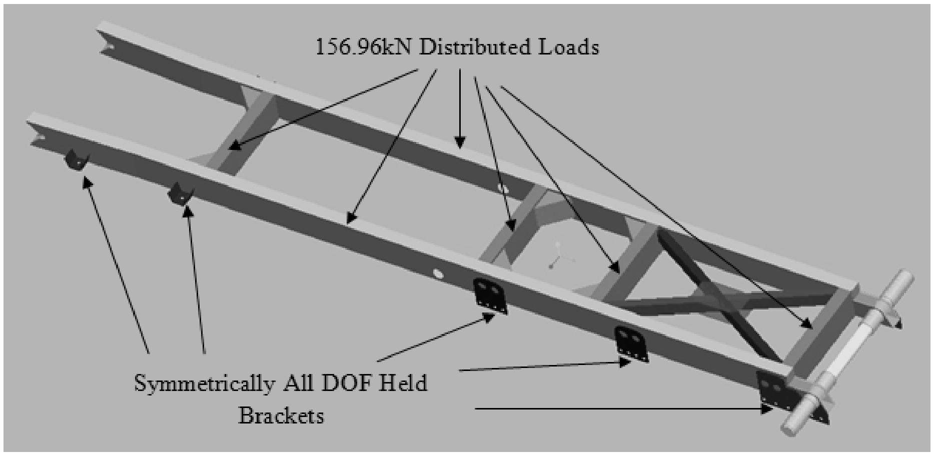


**Figure 2.** Distributed load and constraints.

For the structural analysis, Finite Element Model was prepared. Meshed finite element model of the truck chassis is given in figure 3.

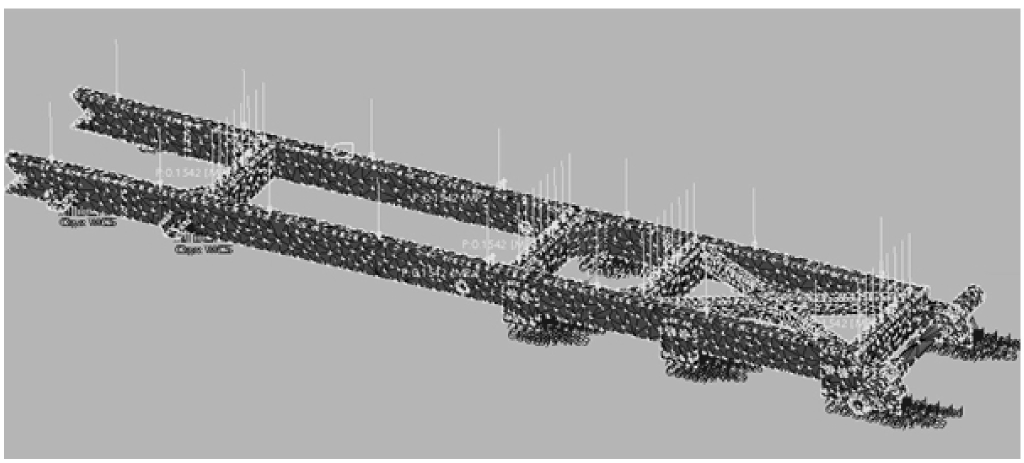

**Figure 3.** Truck chassis Finite Element Model.

To obtain a reliable and robust chassis design, structural simulations of thickness optimizations were carried out with the help of Pro_Mechanica code. The thickness of 6mm, 5mm and 4mm sectioned chassis structures are analyzed and evaluated. The analyses were processed with static and structural methods. The results are compared by the Von-Misses Stresses, strains and total displacements.

## RESULTS AND DISCUSSION

In daily usage 6mm sectioned chassis is reliable but heavy and expensive. For decreasing the thickness of the chassis profile, structural thickness optimizations were performed for 6mm, 5mm and 4mm. The total displacements for the frame thickness of 6mm, thickness of 5mm and thickness of 4mm, can be seen in figure 4-6.

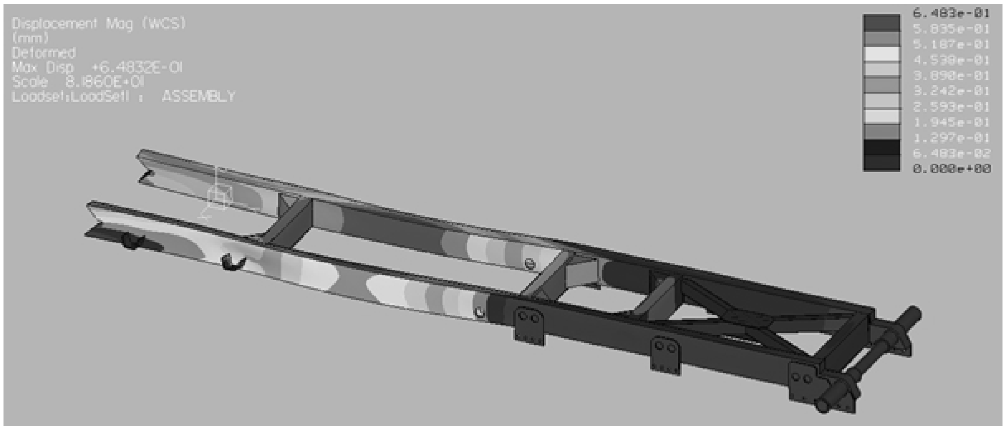


**Figure 4.** Total displacement results behavior for the thickness of 6mm sectioned truck chassis.

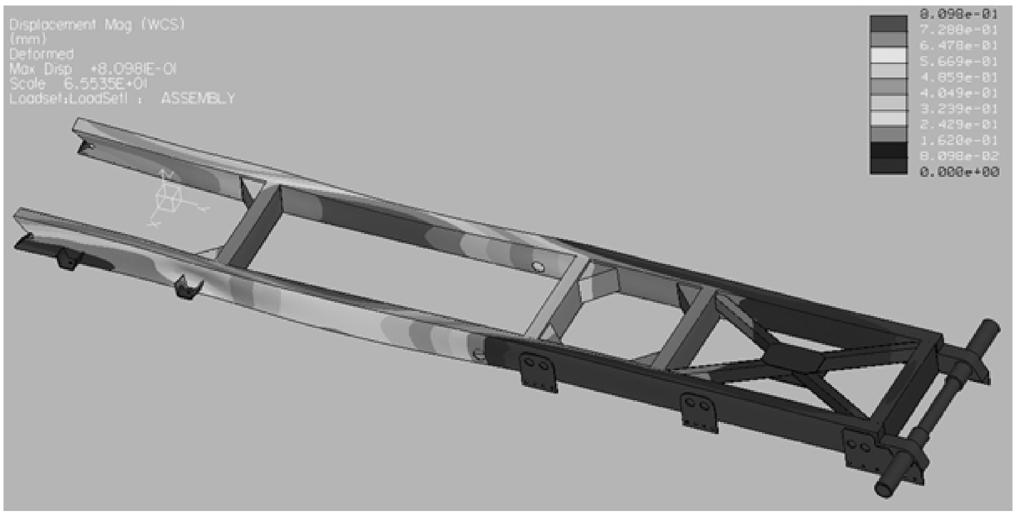


**Figure 5.** Total displacement results behavior for the thickness of 5mm sectioned truck chassis.

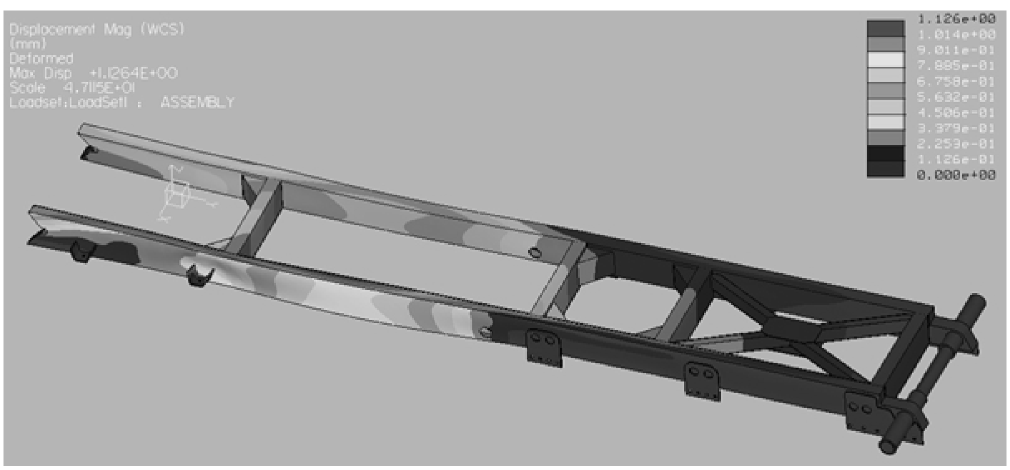


**Figure 6.** Total displacement results behavior for the thickness of 4mm sectioned truck chassis.

For comparing more detailed, displacement results should be supported with the help of maximum Von_Misses stresses and the strains. To see whole picture of the finite element analyses of the structural optimization max. stresses, max. strains and total displacements are given in table 2.

**Table 2:** Max. stresses, max. strains and total displacements of the Truck Frames.

| Chassis Section Thicknesses | **Max. Von-Misses Stress (MPa)** | **Max. Principle Strain (%)** | **Total Displacement (mm)** |
|---|---|---|---|
| **6mm** | 857.9 | 0.005155 | 0.6483 |
| **5mm** | 945.6 | 0.00566 | 0.8098 |
| **4mm** | 1045 | 0.006246 | 1.126 |

In the static analyses of Ford 3530 chassis, thickness of 6mm (original model), 5mm and 4mm square profile of chassis about 16t linear distributed load condition were examined.

Broken stress value of used St. 52.3 steel material is about 350-400MPa. In finite element analysis the stress values can be more than these values. The reason is the manufacturer requirements as a linear, elastic and static analysis. In the elastic analysis, stress value is getting bigger without encountering any resistance. In addition the static tensile tests are processed in the single direction and axis. In the reality loads can be effected different angles. This situation makes the max. stress value is bigger. In the chassis analyses max. Von_Misses stresses for 6mm is: 857.9MPa, 5mm: 945.6MPa and 4mm: 1045MPa.

In this structural analysis strains and displacements are more important. Strains are in mm/mm and show the deformation in %. The principle strains are in thickness of 6mm: %0.005155, in thickness of 5mm: %0.00566 and in thickness of 4mm: %0.006246. The analyses strain results for all thicknesses are acceptable in design criteria.

The total displacements are in thickness of 6mm: 0.6483mm, thickness of 5mm: 0.8098mm and the thickness of 4mm: 1.126mm. The displacement values are less than expected. If the truck loaded with 16t (that is the capacity of this chassis), thickness of 4mm chassis, is bending just about 1mm. This is tiny displacement for a heavy truck. Finally the study showed that a finite element modeling and analysis of the used truck chassis is optimized by the cross member element thicknesses.

For further studies fatigue, dynamic etc. loading conditions can be evaluated as a more realistic determination.

## CONCLUSIONS

In this study following results can be drawn:

- The analyses are processed in the static and structural conditions.
- Used 6mm chassis is heavy and expensive.
- For 4mm strain and displacement results are better than expected.
- Thickness of a 4mm truck chassis section profiles can transport a load about 16t, with a 1mm bending.
- The manufacturer is gained much from their expensive chassis, by the optimization analysis of thicknesses for the truck chassis.

## ACKNOWLEDGEMENTS

After these structural analyses in static conditions, the truck chassis manufacturer has changed the profiles thicknesses of their chassis. The manufacturer is selling the chassis to the popular vehicle companies around the world. In addition this project is cutting the expenses of the truck chassis manufacturer.

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# MACHINABILITY OF MAGNESIUM AND ITS ALLOYS

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**Abstract:** Magnesium and magnesium alloys are used in a wide variety of structural applications including portable microelectronics and telecommunication, automotive, materials-handling and aerospace industries due to their low density. The utilization of magnesium alloys as automotive components is remarkably effective to reduce vehicle weight leading to both reduced discharge of air pollutants (i.e. $CO_2$, $SO_X$ and $NO_X$ emissions) and energy consumption. Another emerging area of Mg and its alloys are biomedical applications as biodegradable materials which may lead them to become next-generation materials.

One of the main drawbacks of the Mg and its alloys is their machinability since their chips during machining can be ignited suddenly leading to fire problems. Therefore, new machining methods have to be adopted for machining Mg and its alloys. The aim of this study was to review the machining methods of Mg and its alloys and evaluate the results as a function of their alloy composition and machining parameters.

**Keywords:** Machinability, Magnesium, Magnesium Alloys

## INTRODUCTION

Magnesium and its alloys with a nominal density of around 1.8 g/cm$^3$, is one of the lightest structural metals, which have excellent mechanical properties, including high strength-to-weight and high stiffness-to-weight ratios. They are used in a wide variety of structural applications including portable microelectronics, telecommunication, automotive, materials-handling and aerospace industries due to their low density. The utilization of magnesium alloys as automotive components is remarkably effective to reduce vehicle weight leading to both reduced discharge of air pollutants (i.e. $CO_2$, $SO_X$ and $NO_X$ emissions) and energy consumption. Another emerging area of Mg and its alloys are biomedical applications as biodegradable materials that may lead them to become next-generation materials. In industry, commonly used magnesium alloys could be classified as AZ (aluminium, zinc), AM (aluminium, manganese) and AS (aluminium, silicon) series alloys (King, 2000).

Most magnesium parts are produced by casting processes. Thus, machining of functional elements is usually necessary. They have better machinability than other commonly used metals (Friedrich and Mordike, 2006; Mordike and Ebert, 2001). The machining could be performed under both dry and lubricated conditions. However, the powder-like chips are easily ignited. Therefore, the interest in magnesium and its alloys have grown dramatically in research community to identify new machining technologies in order to prevent ignition during machining as well as reducing their cost of production (Ruzi et al., 2009). Potential problems when machining of magnesium and its alloys are illustrated in Figure 1.

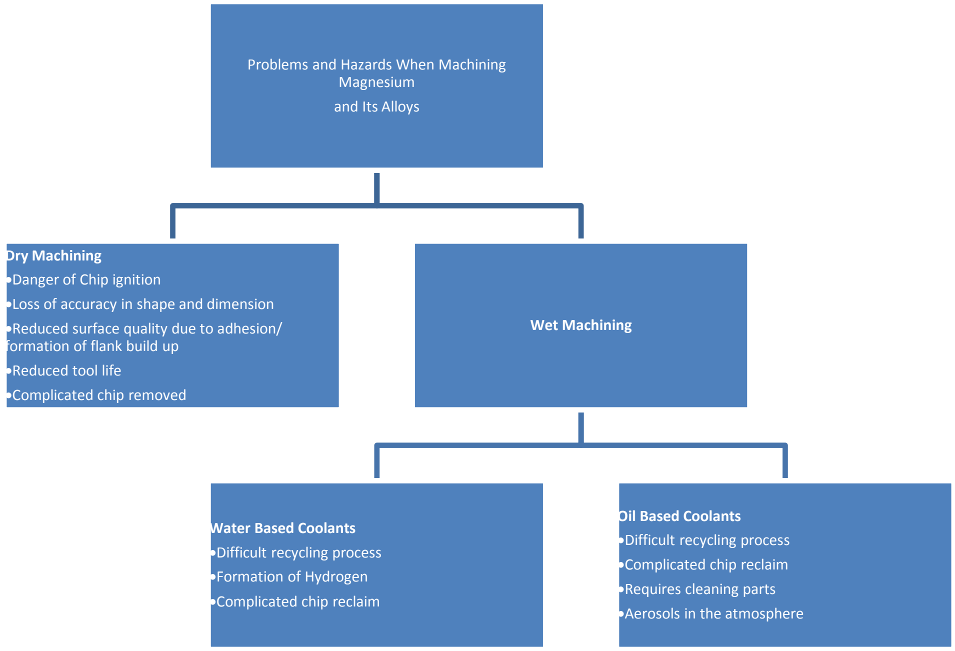


**Figure 1**: Problems and hazards when machining magnesium and its alloys

It is possible to achieve a high cutting speed for magnesium alloy, however, there are concerns that with an increase in cutting speed, there may be serious flank build-up (FBU) due to adhesion between the cutting tool and the workpiece as well as ignition problems. This may cause machining problems related to vibration and tolerances as well as the thermal expansion of magnesium may lead to an insufficient accuracy in geometry and shape of the machined part (Hou et al.,2010). Tönsoff and Winkler carried out turning experiments on the AZ91HP alloy. They observed that FBU due to adhesion between cutting tool and workpiece can occur at cutting speeds of 900 m/min when machining magnesium in dry condition. Friemuth et al. reported chip temperature and the danger of chip ignition could be reduced due to low machining forces when using polycrystalline diamond tools in dry machining of magnesium alloys. Tomac et al. indicated that FBU on cutting edges at speeds in excess of approximately 600 m/min might constitute a problem when turning magnesium alloys. Tomac et al. has also reported that the presence of intermetallic $Mg_{17}Al_{12}$ (*β*) phase in magnesium matrix is responsible for the difference in the machinability of magnesium alloys. Reported experimental tests have revealed that surface defects such as cracks and pores may promote the formation of the FBU problem (Tomac et al , 2008). Fang et al. presented an experimental study of the mean temperature on the flank face for predicting the occurrence of fire in high speed cutting of magnesium alloys. Ozsváth et al. used a new thermo-vision method to examine the chip temperature on rotating milling tool. Arai et al. proposed a method of the chip control by skiving of magnesium alloys and investigated cutting conditions experimentally for generating tubular helical chips, which were not ignited easily.

Viewing the literature published in the academic journals, it can be seen that the research on machining of magnesium alloys mainly focused on the FBU, operation speeds, cutting depth and composition of the alloys affecting the ignition of the chips, accuracy and shape of the machined part. Therefore, this report is intent to discuss the issues of machining of magnesium alloys from the cutting depth, FBU and alloy's composition point of view.

## Machinability of Magnesium Alloys

## Cutting Depth and Speed

The machining is characterized by short-breaking chips, high achievable surface qualities, low-cutting forces, low mechanical and thermal loads on the tool (Denkana et al., 2005). Hou et al. analyzed the influence of depth of cut and cutting speed on ignition condition for AZ91 and AM50A magnesium alloys. In their work (Hou, et al., 2010) chips obtained at different cutting parameters were collected and the resulting data were compared. Thus, the analysis of the relationship between chip morphology and ignition were carried out. Table 1 and Table 2 present ignition conditions of chips at various cutting depths and speeds respectively.

**Table 1:** Ignition condition of AM50A and AZ91D chips at different cutting depths (Hou, et.al., 2010)

| Condition of Ignition | Cutting Depth (μm) | |
|---|---|---|
| | AM50 | AZ91 |
| Sparks | 20 30 40 50 60 | --- |
| Ring of Sparks | ----- | 2 5 7 10 15 |
| Flare | 2 5 7 10 15 | 20 30 40 50 60 |

**Table 2:** Ignition condition of AM50A and AZ91D chips at different cutting speeds (Hou, et.al., 2010)

| Condition of Ignition | Cutting Speed (m/min) | |
|---|---|---|
| | AM50 | AZ91 |
| No | 251 | --- |
| Sparks | 503 | 251, 503 |
| Ring of Sparks | --- | 628, 754, 880 |
| Flare | 628, 754, 880, 1005, 1257 | 1005, 1257 |

It is evident from the Table 1 that the ignition of the chips in the form of sparks initiates at the higher cutting depths and at lower cutting speeds for AM50 alloy. Transition from sparks to ring of to the flares takes place at higher cutting speeds and higher depth of cuts. Figure 2. shows appearance of sparks and flares during machining of AM50A and AZ91 alloys.

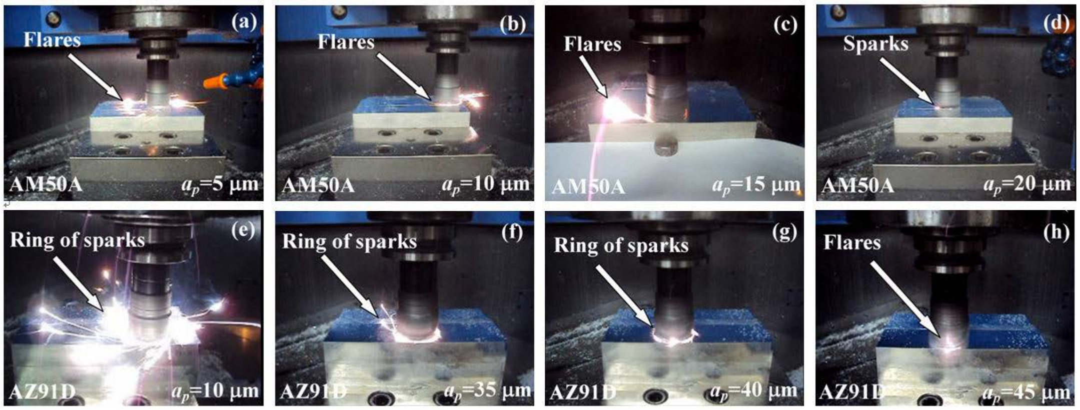


**Figure 2 :** Ignition conditions at different depth of cut during milling AM50A and AZ91D (Hou, et.al., 2010)

In AM50 alloys, 0.2% manganese is added in order to improve its corrosion resistance (Jönsson and Persson, 2010). Aluminium in AM50 alloy, however, results in hardness increase due to solid solution effect that have a negative effect on the machinability of the workpiece material, leading to a FBU and deterioration of the machined surface (Fang, et al., 2005). It is noted from the work of Hou (Hou, et.al., 2010) that ignition of AM50 alloy takes place without showing rings of sparks. However, the inanition of ignition follows formation sparks, ring of sparks then the flare in AZ91 alloy as the cutting speed and cutting depth increased.

It should be taken into account that small, powder like chips and their accumulation is not only a fire hazard, but can also damage machine tool components by polluting sensible areas in dry machining conditions. Furthermore, high process temperature leads to a reduced shape and dimension accuracy of the workpiece and a lower surface quality. For this reason, the concept of lubrication by different solutions as non water-mixable and water-mixed cool-lubricants become favorite. The advantages of the different concepts are briefly summarized here (Ozsváth et al., 2008; Fang, et al., 2005; Tikal et al., 2000):

- Removal of chips.
- Keeping clean the machines.
- Decrease of the tool-wear.
- Avoidance of spark- and dust-formation.
- Lubrication of ways.
- Better heat removal.

However, there also are the dangers of the wet cutting. Through high cutting-speeds, deflagration-danger exists with the oil-treatment (Tikal et al., 2000). With the machining under application of water-mixed emulsion, hydrogen originates in the workroom and in the chip-conveyor. Hydrogen has a low ignition point that should be taken into account. If a fire occurs with the magnesium-treatment with emulsion, the burning magnesium reacts intensively with water. But not only these security-misgivings but also health, ecological and economic aspects should also be taken in to account.

Another problem appears with the recycling of the chips produced by wet machining (Hanko et. al., 2004). The chips, in case of application of lubricants, have to be cleaned first and dried afterwards. If the chips are to be briquetted, the diminution of the fire-danger between formation and recycling, the increased expenses must be considered. (Ozsváth et al., 2008; Tikal et al., 2000).

## Flank Built Up (FBU)

In turning operations, strong adhesive effects between work piece material and most tool materials can be observed at high cutting speeds. This may cause machining problems related to vibration and tolerances that leads to an insufficient quality of the machined surface. Another major concern is the danger of fire ignition when dry machining magnesium alloys (Guo and Salahshoor, 2010). Fires may be prevalent when the melting point (400–$600^{0}$C) is exceeded. As this constitutes a serious problem in an industrial situation, it is necessary to be able to ascertain the temperature during cutting. A study on the measurement of the mean temperature on the flank face in high speed dry cutting of magnesium alloys has been reported (Denkana et al., 2004). Figure 1. illustrates the tool-travel dependent process force components, which are cutting force $F_C$, force in feed direction $F_f$ and passive force $F_p$, when dry machining of AZ91D using uncoated cemented carbide. At a critical tool travel of $l_{ckrit}$ = 350 m, significant variations of the forces were observed, which resulted from FBU attaching to and detaching from the tool flanks (Denkana et al., 2004; Tönsoff and Winkler, 1997).

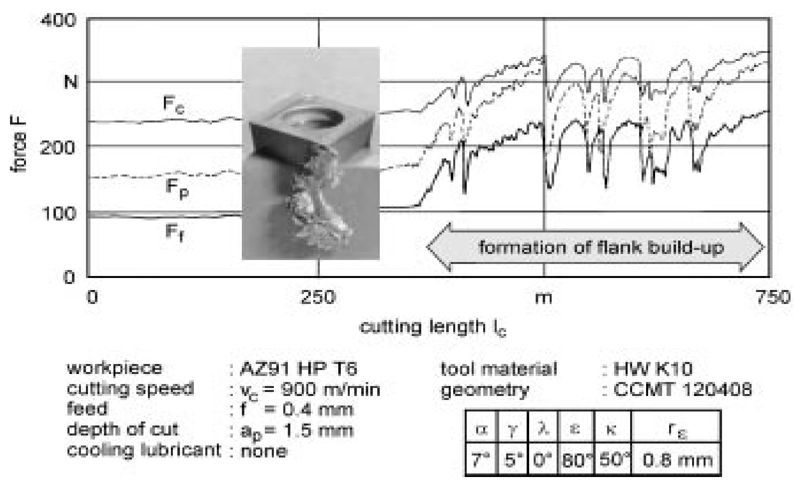


**Figure 3.** Formation of flank build-up (FBU) (Friemuth and Winkler, 1999).

The peak forces of the cutting force $F_c$ exceed the force level before FBU by approximately 45%. For a safe and lowered FBU in the machining of magnesium, usage of coated tools has been reported (Lin et al.,2008; Denkana et al., 2004; Tönsoff and Winkler, 1997). The diamond coatings consist of a low reactivity, a good thermal conductivity and low friction properties against magnesium and its alloys (Ozsváth et. At, 2008). In dry machining, critical concerns such as the heat transfer, adhesion and FBU's can be prevented by usage of coated tools successfully (Ozsváth et al., 2008; Tikal et al., 2000). In a certain range, the surface of the tool influences the machined workpiece surface. Therefore, smooth chemical vapor deposited-diamond polycrystalline (CVD-DP) coatings are in development (Tikal et al., 2000; Tönsoff and Winkler, 1997). Adhesion can be observed on the uncoated cemented carbide grades and TiN-coated inserts. After a cutting length of approx. $l_c$ = 350 m, adhesion leads to a FBU problem. Good results are achieved when machining magnesium with DP-tipped an CVD-DP-coated inserts (Lin et al.,2008; Denkana et al., 2004). The formation of FBU can be eliminated by the use of a suitable cutting fluid or a polycrystalline diamond (PCD) tool. Burnishing operations are a useful mean to improve surface quality, surface hardness and to induce compressive stresses in the subsurface layers if adequate burnishing conditions are chosen.

There is also a relation between tool coatings and cutting speed. In low speed cutting, the coating of the cutting tool is found to be removed due to a high cutting force, resulting from low cutting temperature, and abrasion dominates tool wear (Denkana et al., 2004). When the cutting speed is increased, a protective layer resulting from the diffusion of the cutting tool starts to form on the chip-tool interface. This layer works as a diffusion barrier. Hence, tool wear rate is reduced and the usable life of the tool is prolonged. However, when the cutting speed is further increased, cutting temperature becomes the dominant factor instead of the cutting force. The high cutting speed causes inhomogeneous shear strain, and a transition from continuous chip to saw-tooth chip occurs.

The influence of different cutting tool geometries on cutting and backing forces as well as surface formation in turning is affects the FBU. Therefore, optimizing of rake angles is also in consideration in order to reduce FBU and high cost of coated tools (Gariboldi, 2003). Uncoated carbide tools and tools with polycrystalline diamond (DP) tips as well as TiN and diamond coated carbide tools with different rake angles have been reported (Ozsváth et al., 2008; Fang et. al., 2005; Denkana, 2000). FBU can be avoided by using adapted clearance angles or coated tools. The use of cooling lubricants is another possibility to improve FBU and therefore surface characteristics but may cause the danger of ignition of hydrogen that can be formed when magnesium reacts with water based coolants. The use of oil should be avoided because of difficult chip handling and higher costs.

### Alloy Compositions

Adding alloying elements is one of the effective methods to prevent the ignition of magnesium alloys. The formed heterogeneous phases, formed by alloying additions, can cause discontinuity in the matrix weakening the cohesive forces at the locations of discontinuity, which facilitates the easy breaking of chips during the machining process. Aluminium is the main alloying addition to magnesium matrix (e.g to AZ, AM, AS series). The maximum solubility for aluminium in magnesium in the solid state is 12.7% at 436°C and goes down to 2% at ambient temperature. In the cast condition the $\beta$ phase is formed along the grain boundaries of the magnesium matrix (Lin et. at., 2010). This is especially the case if the cooling rate after processing is relatively low, e.g, in sand casting. It has been reported (Tomac et.al, 2008) that the critical cutting speed increases with decreasing aluminium content. It has been reported that the addition of rare-earth elements, such as yttrium and cerium, into alloys has been used to improve their oxidation resistance (Hanko et. al., 2004) implying that the ignition resistance also has been increased. For instance, the ignition temperature of AZ91D magnesium alloys can be much increased by the addition of cerium (Lin et. at., 2010).

## CONCLUSIONS

Literature review highlighted the problems encountered with the machining of magnesium and its alloys are summarized as follows:

- One of the main drawbacks of the Mg and its alloys is their machinability since their chips during machining can be ignited leading to fire problems.

- Dry machining produces high temperature that promotes adhesion between cutting tool/work material as well as FBU when critical cutting speed is exceeded.

- With the machining of magnesium alloys under application of water-mixed emulsion, hydrogen generation results in fire and health hazards. With the wet machining, deflagration danger still exists with the oil-treatment at higher cutting-speeds.

- FBU is initiated by a certain affinity between cutting tool/work materials, sufficient cutting temperature, and the existence of hard particles embedded in the soft matrix.

- Coating of the tool, such as Polycrystalline diamond, helps diminishes formation of FBU's.

- The influence of different rake angles on cutting and backing forces as well as surface formation in turning affects the FBU.

- The form of ignition could be sequenced as spark, ring of sparks and flare depending on cutting speed, depth and composition of the magnesium alloy.

- The ignition of the chips in the form of sparks initiates at the higher depth of cuts and at lower cutting speeds for AM 50 series alloys. Transition from sparks to the flares takes place at higher cutting speeds and higher depth of cuts in AZ 91 series alloys.

- The ignition of chips can be impeded as aluminium content of the magnesium increased especially at finer cutting depths and higher cutting speeds.

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